ELECTROMAGNETIC SEDIMENT ELECTRICAL CONDUCTIVITY STUDY IN THE KINGSTON AREA

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Water Resources Branch
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ACKNOWLEDGEMENTS

SUMMARY

The sediment electromagnetic conductivity survey was carried out in September 1989 by GEOMAR at two locations in the Kingston area, Cataraqui Bay and Parrotts Bay. The preliminary survey results were used by the Ministry as a guiding tool to define optimal locations for sampling stations. The study determined the spatial distribution of sediment electrical conductivity anomalies (areas of high sediment conductivity, containing contaminated soft material) in the surficial sediments in the area. Since the electromagnetic measurements are very fast to carry out a relatively high spatial resolution can be achieved. Measurements were done with the Geonics EM-38 electromagnetic terrain conductivity meter adopted to a freshwater environment. Data were collected by a digital data logger, and in addition by a one channel analog chart recorder. The line contour maps of sediment conductivity (reduced to 25 °C) and plotted profile traces showed the spatial distribution of potential contaminants along the lake bottom.

REPORT ORGANIZATION

The report consists of the main text and four Appendixes. The text contains only the most representative figures including color contour maps. All maps and traces are found in the Appendixes. Appendix A contains the survey plan and contour maps and Appendix B contains plots of profile traces for Cataraqui Bay. Similarly, Appendixes C and D contain the survey plan, contour maps, and profile traces for Parrots Bay. The set of traces for each survey is preceded by the corresponding survey plan.

1. INTRODUCTION

1.1 Rationale

There is an increased use of sedimentary data for the determination of the spatial distribution of contaminants along lake or river floors, for locating shore and off-shore contaminant sources and for defining patterns of sediment deposition. The sediment sampling, coring and analysis is expensive and time consuming. Consequently, contaminated zones are often mapped by interpolating relatively few core locations, a practice which results in obvious uncertainty.

The similar problem of mapping contaminated ground water emanating from waste disposal sites is alleviated by using a geophysical approach. One geophysical technique, the electromagnetic method (the measurements by electromagnetic induction, without electrodes) has become widely used in North America in investigations of hazardous wastes and contamination of groundwater (Glaccum et al, 1982; Greenhouse et al, 1983; Valentine et al,1985). The electromagnetic technique provides a fast and easy way to map contaminant plumes and is recognized as a cost-effective method for locating contaminants in shallow subsurface zones. The results of electromagnetic conductivity ground surveys are used as a basis to assess the degree of contamination and to locate and determine the optimum number of drill holes to obtain a more detailed analysis of contaminants.

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The electromagnetic method (described separately below) applied to sedimentology is a very efficient, fast and cost-effective tool for investigating the spatial variation of sediment physical and chemical properties. The electromagnetic measurements can be performed very rapidly, and a relatively high spatial resolution can be achieved. The virtually continuous method of data acquisition is especially important in investigations of highly anomalous areas similar to the study areas in this project. Using the computer programs developed in this study, a preliminary review of collected data can be obtained almost immediately. The spatial resolution of the measurements can be instantly increased in areas of concern and in addition, any possibly unsatisfactory part of the survey can be repeated without leaving the survey site.

1.2 The electromagnetic (inductive) method

The theory of the electromagnetic method is very well described in literature (Kaufmann, 1985); applications of the ground conductivity meters are given in Geonics Limited publications (McNeill 1980a; 1980b; and 1985). In the electromagnetic method two coils (transmitter and receiver) are situated on or near the sediment-water interface, or other ground surface. An alternating voltage applied to the transmitter coil causes electrical eddy currents to be induced in the ground. The electrical currents thus induced are proportional to the electrical conductivity of the medium. These currents in turn, generate a secondary magnetic field that

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is detected and measured by the receiver. The configuration of the antennas, electric currents and magnetic field is shown in Figure 1.1. The measured quantity is usually the apparent conductivity of the material. Since this is a non contact technique, the measurements are very reliable and highly repeatable, and therefore suitable for monitoring purposes.
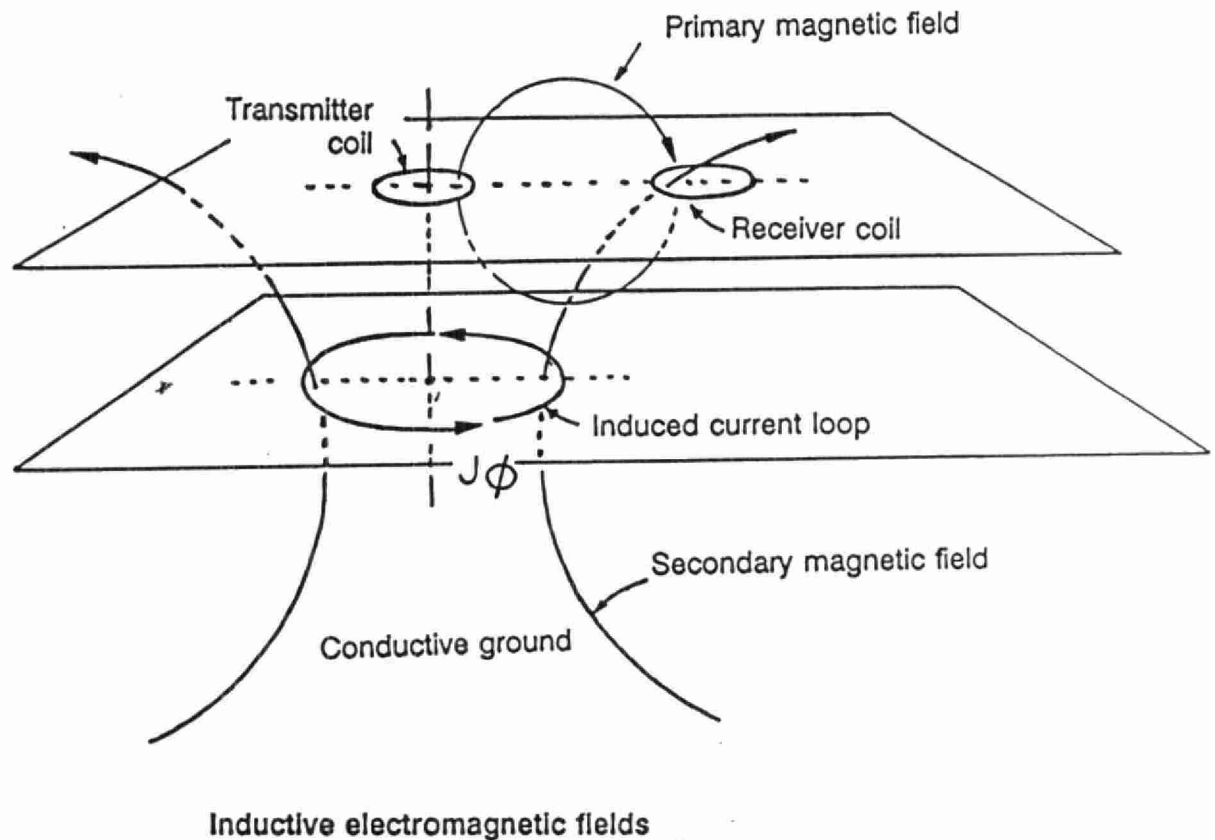
Primary magnetic field

Transmitter coil

Receiver coil

Induced current loop

$J\phi$

Secondary magnetic field

Conductive ground

Inductive electromagnetic fields

Figure 1.1

1.3 Description of study area

The work program of this project consisted of measurements of the sediment electrical conductivity in the North Channel area of Lake Ontario, near Kingston. Surveys were conducted in two areas, Cataraqui Bay and Parrotts Bay. The potential source of contaminated sediments in these two bays include large industries and an STP outfall, Dupont Canada Ltd. and Kingston TWP STP located in the Cataraqui Bay area, and Millhaven Fibres Ltd. and Celanese in Parrots Bay.

2. METHODS

2.1 Instrumentation

The Geomar electromagnetic underwater system consists of the Geonics EM-38 ground conductivity meter, waterproof enclosure, specific conductivity sensor, temperature sensor, interfacing cable and digital data acquisition system.

The EM-38 ground conductivity meter was designed to measure the apparent conductivity of soil and rock near the surface. This instrument is widely used in soil salinity investigations and in areas where a knowledge of near- surface conductivity can be useful, such as general mapping and archaeology. The unit employs a coplanar coil geometry with an intercoil spacing of 1 m and can be used in the vertical or horizontal dipole mode. The horizontal dipole mode provides a shallower depth of exploration. In this configuration the material contained in the top 35 cm layer contributes approximately 50% of the meter reading, and all material above 15 cm contributes approximately 25%. Therefore, the instrument employed in the horizontal dipole mode is very sensitive to variations of the surficial sediment conductivity. The response of the instrument in both modes as a function of depth is shown in Figure 2.1.

The EM-38 conductivity meter is placed in a waterproof enclosure. The weight of the enclosure is 65 kg, the size is approximately 0.8 m wide and 1.4 m long. The design of the underwater enclosure and 60 m long interfacing cable
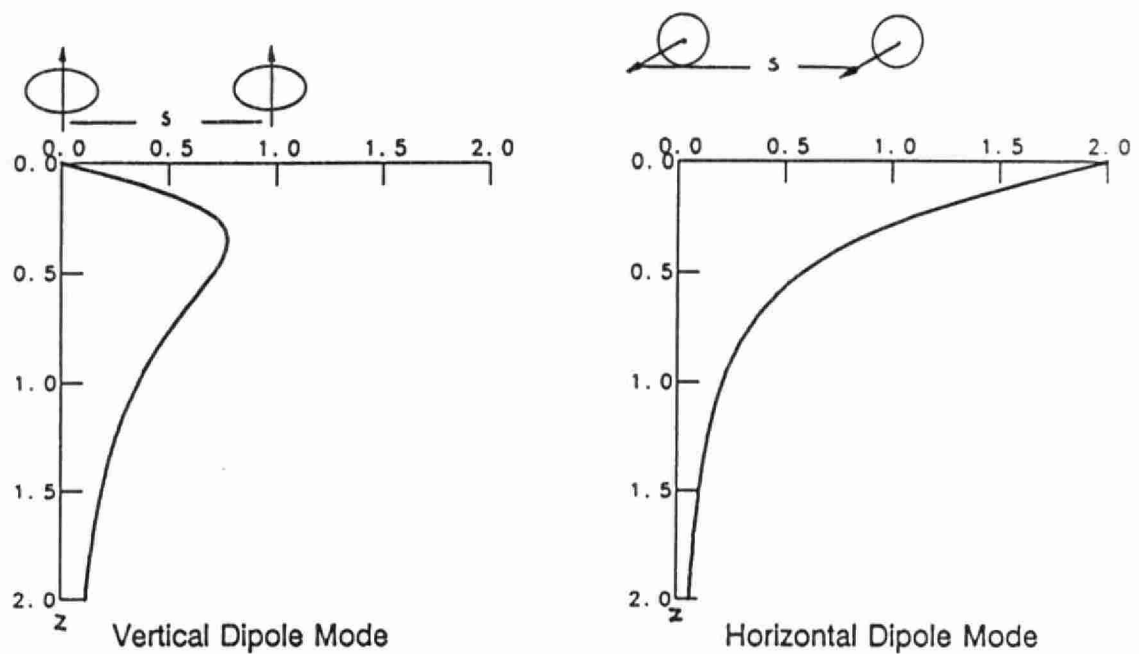
RESPONSE AS A FUNCTION OF DEPTH

Figure 2.1

allow towing of the system firmly along the lake or river bottom at a speed of up to 5 km/h at a depth not exceeding 25 m. In deeper areas, a longer interfacing cable has to be used. The shape of the instrument allows small underwater obstructions to be overcome. In areas where larger obstructions may appear the instrument can be simply lowered from the boat at any desired reading station. The field configuration of the GEOMAR system is shown on Figure 2.2.

The specific conductivity and temperature of the overlying water are measured by appropriate sensors mounted on the base. The sensors are connected to a conductivity and temperature meter, which is interfaced to the data logger. All three readings, apparent sediment conductivity, specific conductivity and temperature of the water are taken simultaneously. The water temperature is
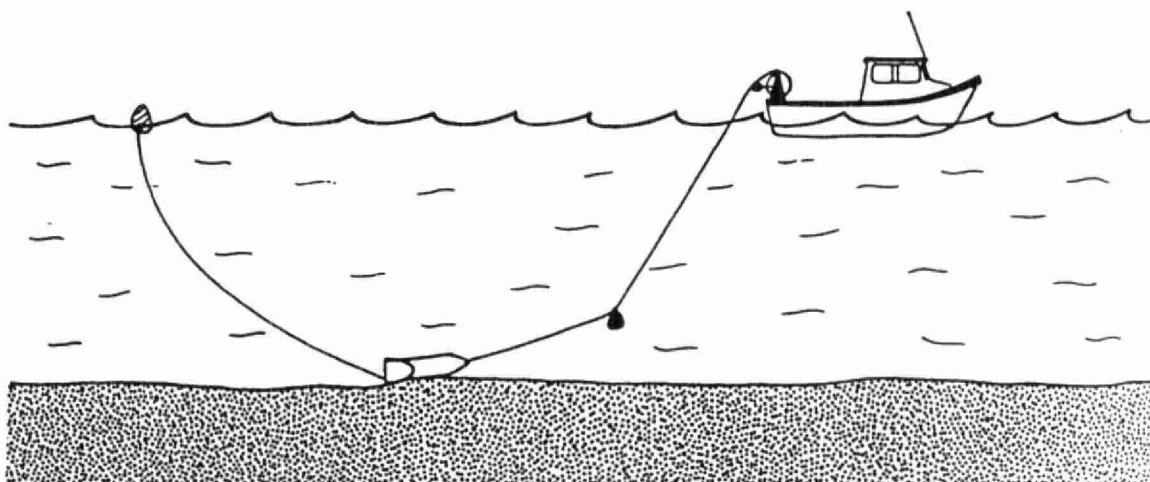
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Figure 2.2 The field configuration of the system

used to reduce the specific conductivity of the water to the standard temperature (25°C) as described below, and thence calculate the sediment conductivity.

2.2 Data acquisition

The underwater instrument is connected by interfacing cable to the Omnidata Polycorder 516C digital data logger placed in the boat. The specially designed data acquisition program EMSUB was written in Polycode for the data logger. Using the logger program, a survey line number, position of the start station, chosen time interval, and any comments during survey can be entered; collected data can be subsequently transferred to the on-board IBM PC compatible computer. All three readings (apparent sediment conductivity, specific water conductivity and temperature) are recorded simultaneously. These values are

displayed on the logger display as well. The measurements can be recorded in continuous, automatic mode (an on/off software switch is provided) with optional time intervals (minimum 2 seconds with the display on, 1 second with the display off). Additionally, a mounted fiducial switch triggers the data logger when manual operation is desired. The survey was done mostly in the automatic mode. The lowest time increment used during the surveys was 2 seconds, which corresponds to about 1.2 m spacing between reading stations. Finer time spacing is possible without display function. However, the usage of a small time interval generates a large amount of collected data and the capacity of the logger solid state memory is filled up in a relatively short time, e.g. half a day. During this survey, an on-board laptop computer was used to transfer data from the logger. Simultaneously with the digital data logger, the analog one channel chart recorder was used to plot a continuous trace of the measured apparent conductivity.

2.3 Data processing

The data collected by the logger were analyzed using an IBM PC compatible computer. Geomar has developed a computer program GEOSUB that allows processing and reduction of underwater electromagnetic sediment conductivity, water specific conductivity and temperature data in conjunction with all navigation data. The navigation parameters (navigation procedure is discussed below) were recorded manually. Since many details were recorded, the

interpretation of the navigation data consumed far more time than any other portion of the time required for data reduction.

The data are presented as plots of sediment conductivity, and temperature and specific conductivity of the overlying water for every survey line. All comments that can help in location like buoys and docks are marked on the plots. The GEOSUB program was used to prepare an input file for a contouring program. The contour maps were constructed using the Geosoft Contouring Software. When readings failed to agree at points where two perpendicular transects crossed, the averaged value was taken for calculations. The location data plotted on the contour maps: line shores, buildings, buoys, shore areas were prepared separately using GEOMAR software and Houston Instrument digitizer. The plotted maps are scaled in metres from the reference point, given as a latitude and longitude. The conductivity values are given in μS/cm and are reduced to the standard temperature (25°C) using the formula for a sodium chloride solution (McNeill, 1980) given below.

$$\sigma(T) = \sigma(25°C)[1 + \beta(T\text{-}25°C)]$$

where σ = electrical conductivity
β = 2.2 X 10^{-2} per °C
T = temperature (°C) at which conductivity is
to be calculated.

2.4 Data presentation

The results of the surveys are presented as color contour maps, line contour maps and profile plots. The color maps are especially useful in areas when only a single line can be profiled. The maps of the survey geometry, the sediment electrical conductivity, the bottom water specific conductivity, and bottom water temperature are presented separately for each survey. The plotted maps include topographical features like shorelines, buoys, STP and industrial outfalls, etc.

While computer or hand generated contour maps are always subject to filtering and interpolation, the profiles are plotted without using any filters, or smoothing techniques. The presented traces show the real resolution of the method. Wherever it was possible the intersections with other profiles were noted. The profiles for each area and survey are plotted in the same conductivity range. The distance along the survey line is calculated from the starting point of the line or from the intersection with the base line zero. The orientation of all traces is noted at the vertical axes. The actual direction of vessel movement during the profiling is indicated at the top of the plot.

2.5 Navigation

The navigation during surveys was performed using an on-board radar system, hydrographic charts and visual observations. At every measured point distances from two known on shore points were measured using the radar system. According to the captain of the MOE vessel the accuracy of such measurements is better than +/- 10 metres. These measurements were taken at the beginning of and end of every survey line, and during profiling, on average every 100 to 200 metres. The radar readings were recorded manually.

All possible visual features that could help the positioning were noted. In many cases the surveyed line started or ended at known points on the shore. The other recorded points were alignment of characteristic off- and on shore points, e.g. buoys and highrise buildings.

The radar recordings and above observations were used during data reduction. Particular station locations were calculated using the assumption that the boat moved in a straight line at constant speed between two known points. The largest error could occur when the wind was across or opposite to the direction of the profiling, because under these conditions it is difficult to navigate in a straight line. For this reason, some of the transects were repeated, and most were done with the wind direction. An additional factor was the presence of a large amount of weeds in Cataraqui Bay, which resulted in a lower speed of the boat while profiling. Assuming that the boat speed would change not more than 50%, the distance between two known points (the radar readings and recorded

observations) was not larger than 300 m, and average station spacing was 3 to 5 metres the potential positioning error of each station was less than the anticipated accuracy of the survey positioning, +/- 25 metres. During point by point measurements the error of the instrument position should not exceed +/- 10 metres.

The hydrographic charts were used to locate shore lines, buoys and characteristic points on the shore. Kingston Harbour and Approaches chart number 1459 edition July 14, 1989, was used for the Cataraqui Bay survey, while Kingston to Upper Gap chart number 2005, edition July 21, 1989, was used in Parrotts Bay. Both charts are published by The Canadian Hydrographic Service.

During the entire data analysis, the implementation of all the navigation records described above was the most laborious task. This time consuming part of the work was necessary in order to achieve the intended accuracy of the survey (+/- 25 metres).

2.6 Technical problems during field work

The experience with technical problems encountered during preceding surveys in Toronto Waterfront area resulted in construction of the improved underwater enclosure and two much stronger towing cables, that were employed during measurements in North Channel area.

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It was learned that during even moderate winds it is very difficult to keep the boat towing equipment along a straight line at a slow, constant speed. During windy days profiling was done only with the wind. This procedure required more time and effort spent for removing the instrument from the water at the end of every profile line, but it was required for accurate survey work.

While the problems with underwater obstructions were not serious during good weather, they are very serious during windy days. The measurements can be conducted well even in the presence of 1 m waves, but whenever the instrument was stranded in such weather, it was very difficult to handle the boat while removing the equipment.

The other problem that was encountered during the initial surveys, was moisture condensation in the underwater enclosure under conditions of high atmospheric temperature and humidity. The humid air was enclosed with the instrument in the underwater housing. Moisture later condensed on the sensitive electronic parts of the instrument when submerged in the relatively cold water. This problem was solved by additional drying of the underwater enclosure and by using silica gel packages.

Another problem that appeared during the survey in Kingston was associated with the size and power of the boat. The Geomar 17' boat used in the Toronto Waterfront surveys is relatively light and equipped with a slow 65 H.P. motor. In the Kingston area the MOE 25' aluminum boat with twin 512 H.P. engines was used. The boat had to be run on a single engine which resulted in difficulties in profiling along a straight line. This speed was still too high to conduct

measurements in areas deeper than 15 to 20 metres. In deeper areas the instrument was lifted off the bottom, which could be observed as a flatter curve without many details. The employed analog chart recorder plotting the apparent conductivity curve in real time was very helpful in such cases. In deeper areas of Parrotts Bay, and outside of Cataraqui Bay measurements were conducted using point measurements. This resulted in a smaller but more reliable number of measured points.

The small boat was stopped when the instrument hit larger underwater obstructions, usually large stones or rocks. The shallower parts of Parrots Bay and an area outside of Cataraqui Bay consist of exposed bedrock. The relatively heavy and fast MOE boat didn't react on many obstructions and the underwater enclosure had to be reinforced after the first survey day in the Kingston area.

3. RESULTS

3.1 General Overview

The detailed results of the study will be discussed below separately for each area. The bedrock, which was exposed or overlaid by very thin layer of soft material, was delineated very well in both areas. During part of the Parrotts Bay survey the MOE echo-sounder was used. This allowed the hard and soft bottom to be distinguished in real time. An example can be seen in Figure 3.1, where the original analog chart recorder and echo-sounder print outs of part of profile line 8 surveyed in Parrotts Bay are presented. The analog chart recorder plots apparent total conductivity of combined sediment and water, not corrected for temperature; therefore the curve slightly differs from that presented on figure D-5. However, the general shape of the curve remains the same. The multiple echo reflected from the rock on the echo-sounder and low conductivity on the chart recorder can be observed at the same time. Reflections from smaller stones and corresponding peaks on the conductivity curve are shown to the left of the peak generated by the large rock. These small peaks are the result of strong and sudden mechanical shocks, and are filtered out during contour map preparation. In other areas the softer bottom appears on the echo-sounder, corresponding to areas of higher conductivity.

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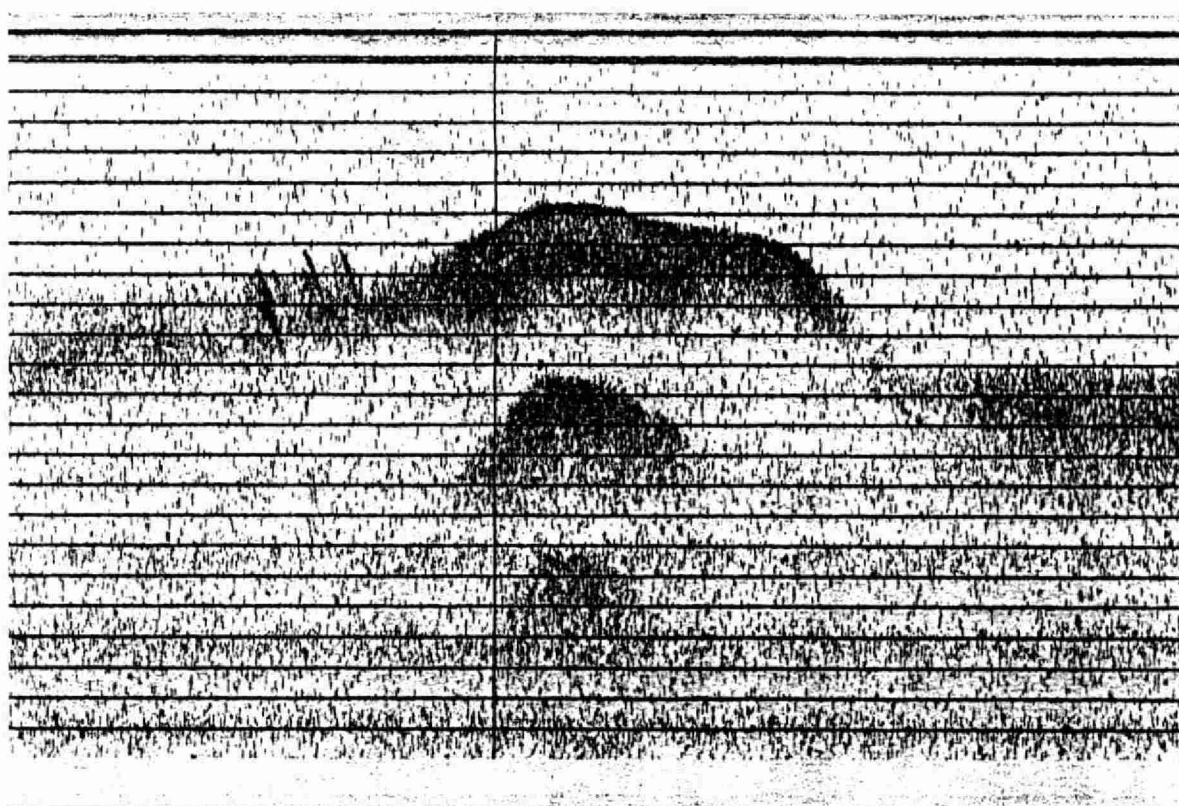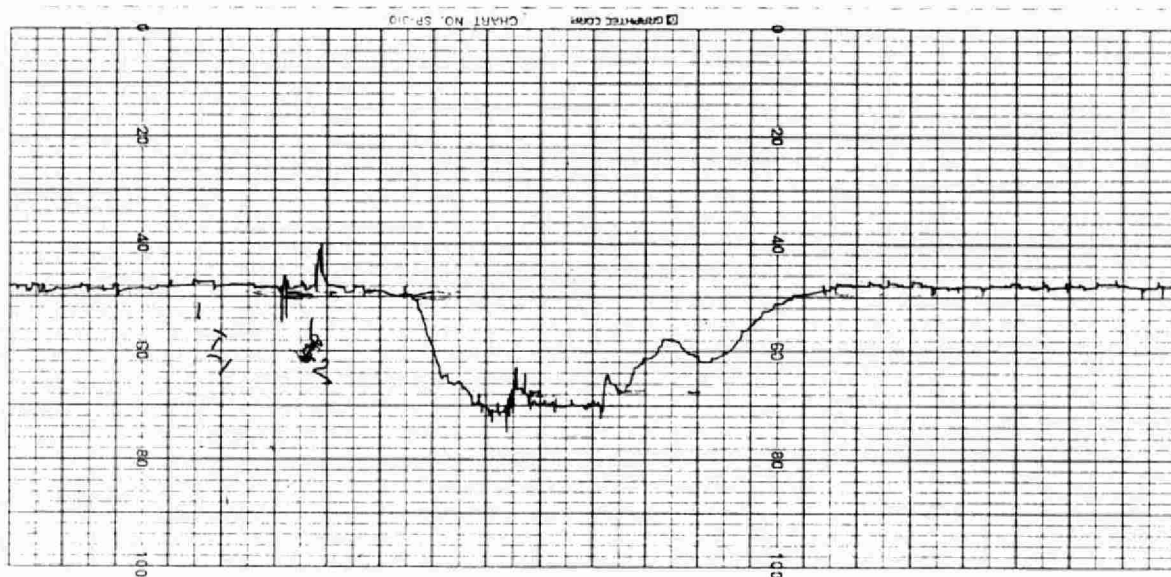
Figure 3.1 Comparison of the echo-sounder and conductivity
recorder outputs.

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In both Cataraqui and Parrotts Bay survey areas, the sediment electrical conductivity was found to be elevated in deeper parts of the North Channel. It should be noted that the bottom water conductivity is also higher in these areas.

3.2 Cataraqui Bay

The survey plan is shown in Figure 3.2. The color contour maps for sediment conductivity, bottom water conductivity and temperature maps are presented in Figures 3.3, 3.4, and 3.5, respectively. Line contour maps are presented in Appendix A, and all plots of profile traces are given in Appendix B. The Cataraqui Bay study area can be divided naturally into two parts: (a) the interior, which is bounded on the west and north by the mainland, and on the east by the Kingston elevator filling (which has been extended by recent additional filling), and breakwater wall in the south; and (b) the outside area, which is south of the breakwater wall. Each area was surveyed in one day.

In the interior of Cataraqui Bay sediment conductivity is elevated in the eastern part of the bay, in an area adjacent to the outfall of Dupont Canada Ltd. This area is very shallow (water depth less than 1.2 metres). Therefore, the correction for the air effect should be considered. The air, a resistive medium, is detected by the instrument at depths of less than one meter, resulting in a reduced value of the measured apparent conductivity. The conductivity of this bottom area is higher than in any other interior part of the bay. It is thus concluded that higher

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conductivity associated with the sediment and water contamination originates from the industrial outfall. It should be noted that the water temperature in the latter area is lower. This effect is most likely caused by the fact that in September the lake water is at its warmest state, while the outfall water has begun to cool.

The second significant high sediment conductivity anomaly in the interior part of Cataraqui Bay is located close to Kingston Elevator (east of sample point 13). There is no corresponding water conductivity anomaly in this area, which indicates that the anomaly is not created by any effluent or groundwater seepage. The higher sediment conductivity can also be observed in the area between Kingston Elevator and Richardson Wharf. Unfortunately, there was no time to profile more than one line in this area.

Areas of very low sediment conductivity can be observed south and west of Kingston Elevator. The most probable explanation of these features is the removal by dredging of the soft sediments. In such areas the instrument can "see" the bedrock, which is resistive.

A zone of high variability in sediment conductivity can be observed at the entrance to Cataraqui Bay, in the vicinity of the buoy KJ3. The very high peak at 3500 μS/cm, is found on profile line 12, Figure B-14 in Appendix B. This profile is also presented on Figure 3.6, together with the trace plotted in real time by analog chart recorder. This anomaly may have been caused by a buried, plate-like metallic object.

Areas of exposed bedrock, with very low sediment conductivity, can be easily distinguished in the outside area of Cataraqui Bay. Deeper areas are

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distinguished by relatively high sediment conductivity. Due to difficulties discussed in section 2.6 the most southern transect was profiled using the point by point method.

The area in the vicinity of the Kingston Township STP outfall (south of Carruthers Point) was profiled using the latter method. A large amount of variations can be seen in this area; however, there were too few measured points in this area to draw any final conclusion. In addition, the survey day was windy, and immediately west of the outfall there are several intake pipes. The captain of the MOE boat was afraid that the underwater instrument might have been stranded, or underwater intake equipment damaged.

The bottom water conductivity in the outside zone of Cataraqui Bay increases with the depth, while the temperature of the bottom water decreases with the depth. Since the formula for temperature correction might not be completely accurate for lake water, the water conductivity was plotted without temperature correction (figure 3.4a). A comparison of figures 3.4 and 3.4a shows that in the inner portion of the bay, where temperature is more evenly distributed, both maps are similar. On the other hand, because of the larger temperature variation in the outside part of the bay, figures 3.4 and 3.4a are very different. At the same time, comparison of figures 3.4, 3.4a and 3.5 shows that in this part of the survey area the conductivity of the water reduced to temperature 25°C behaves more as the function of the temperature than the measured conductivity. This suggests that the formula used for sodium chloride solution should not be applied to lake water. The conductive water plume at the Kingston TWP STP outfall can be better distin-

guished in figure 3.4a.

Similarly, a map for the sediment conductivity without the temperature correction was constructed (figure 3.3a). This map should be viewed as a conductivity of the sediments assuming a constant sediment temperature. Since the temperature below the sediment-water interface was not measured, this approach might be better than the assumption that the water and sediment temperatures are equal. The spatial distribution of the uncorrected and corrected sediment conductivity (figures 3.3 and 3.3a) is similar. The fact that the temperature correction is very significant for the water conductivity but small for the sediment conductivity results from the very small range of the water conductivity variation compared to the large range of the sediment conductivity values.

Figure 3.2

Figure 3.3

Map labels and legend text:

200 W · 0 · 200 E · 400 E · 600 E · 800 E · 1000 E · 1200 E · 1400 E

1400 N · 1200 N · 1000 N · 800 N · 600 N · 400 N · 200 N

DUPONT CANADA LTD

CATARAQUI BAY

KINGSTON

DUPONT CANADA OUTLET

Carruthers Point

KINGSTON TWP STR OUTFALL

Breakwater Wall

Kingston Elevator

Richardson Wharf

Scale 1:6000
100   0   100   200   300
(metres)

ONTARIO MINISTRY OF THE ENVIRONMENT

CATARAQUI BAY
Lake Ontario, Kingston

SEDIMENT ELECTRICAL CONDUCTIVITY
(at temperature 25C)

Survey carried out
    September 14 & 15, 1989

Electromagnetic Instrument
    in Horizontal Dipoles Mode

Water Conductivity in uS/cm

+ - sediment sample stations
    7, 10, 11, 12, 13,
    C, D, E, F and G

Reference Point 0,0 m
    Lat   44 deg 12.38' N
    Long 76 deg 32.73' W

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Figure 3.3a

Figure 3.4

Figure 3.4a
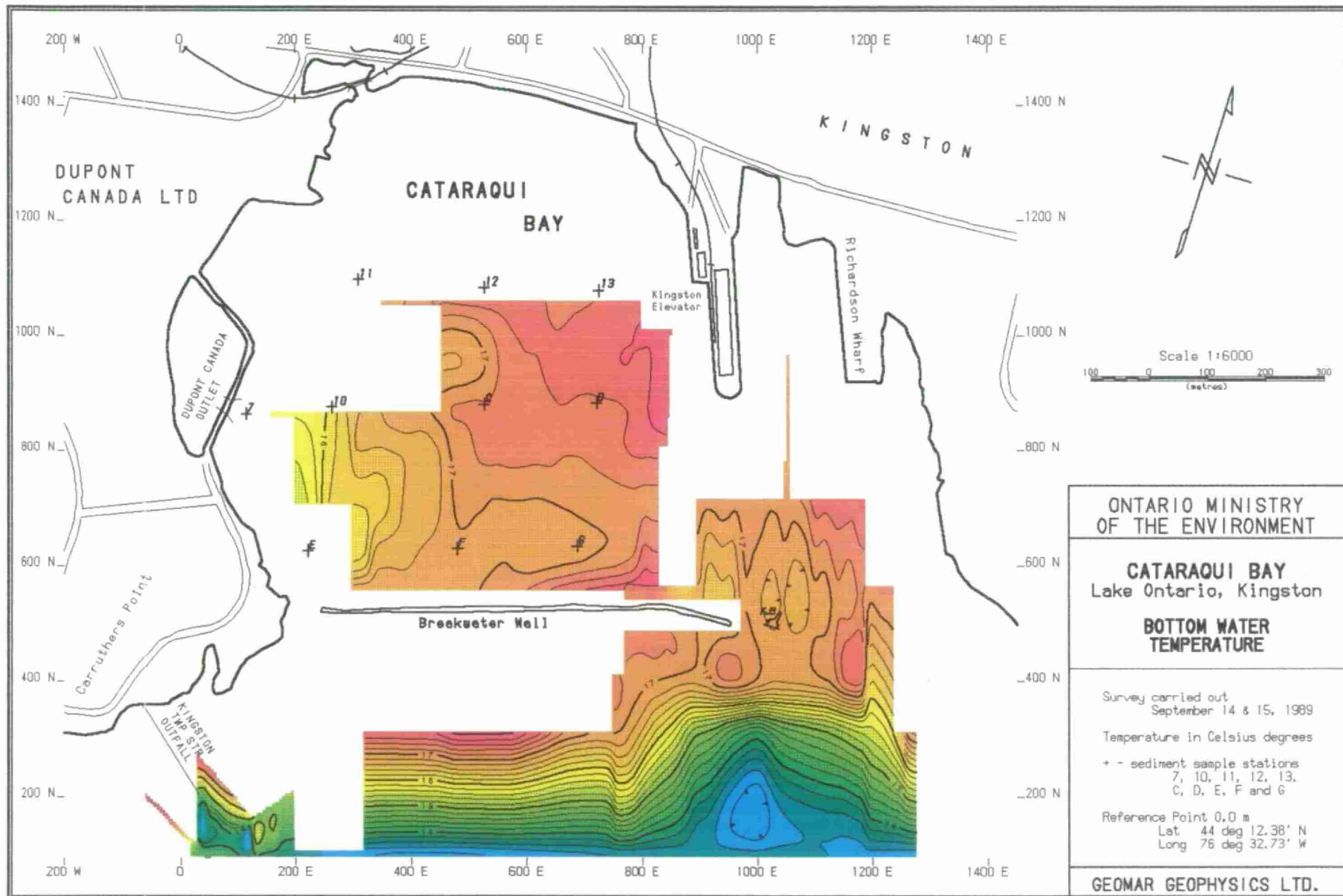
Figure 3.5
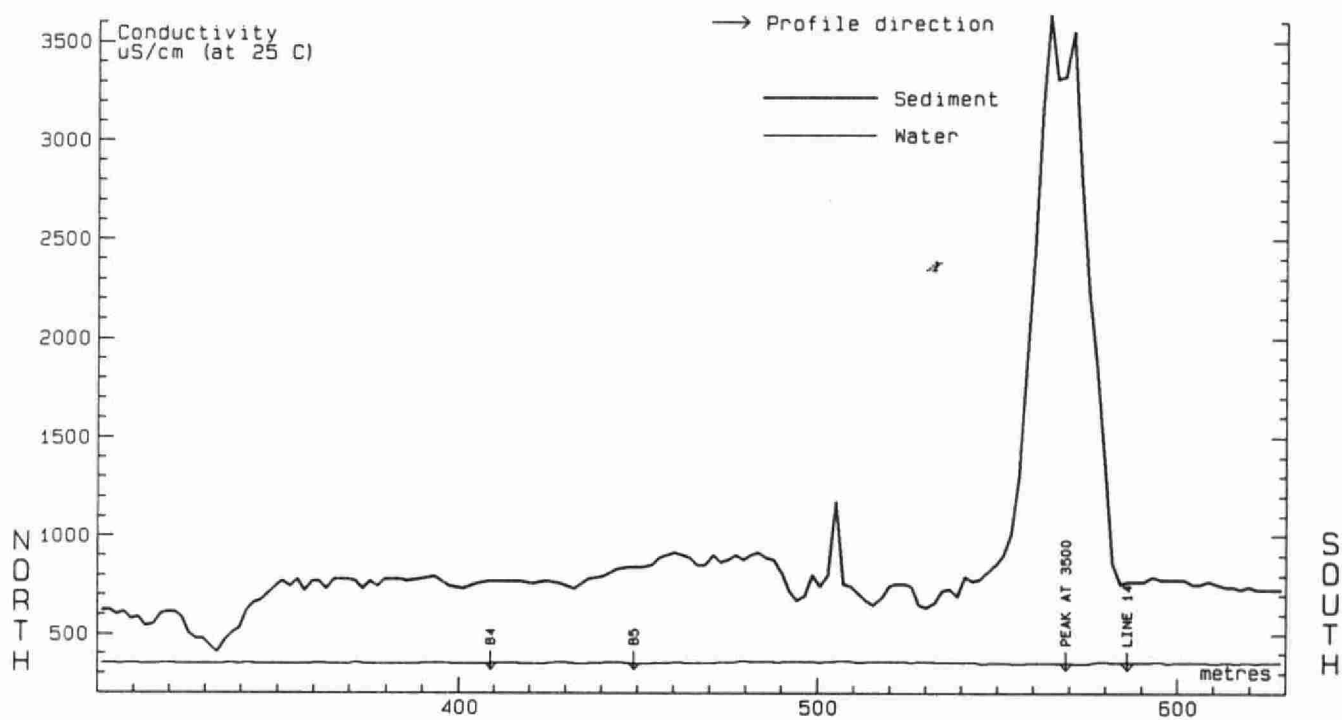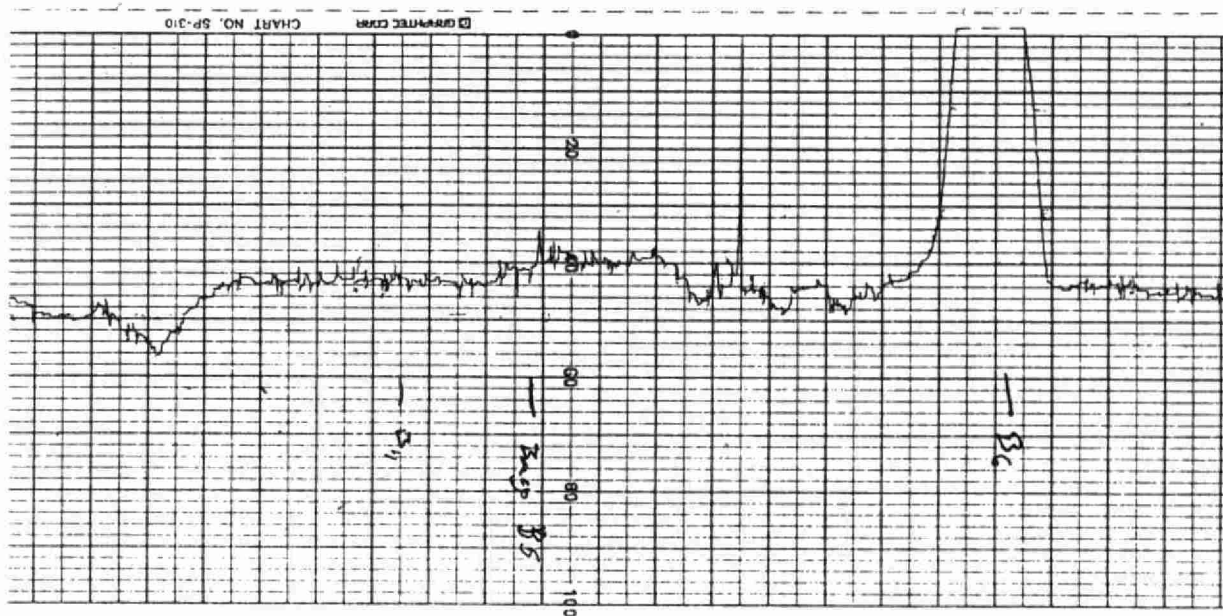
Figure 3.6   Comparison of the same anomaly on chart recorder
and computer printouts.

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3.3 Parrotts Bay

The survey plan for Parrotts Bay is given in Figure 3.7. The color contour maps for the sediment conductivity, bottom water conductivity and temperature are presented in Figures 3.8, 3.9 and 3.10, respectively. Line contour maps are given in Appendix C, and all plots of profile traces are shown in Appendix D. The Parrotts Bay survey was conducted during two days. The first day was spent on continuous profiling of nearshore areas, and the point measurements in deeper parts of the area were conducted during the second field day.

The survey was started at the north-east end of the Parrotts Bay, line 1 on Figure 3.7. This was the very first transect profiled using the MOE boat. Initially, the speed of the boat was too high and the instrument was lifted off the bottom. The effect can be seen on Figure D-1, at the comment "Changed Speed". Since that point only one of the two boat engines was used. The first part of the transect 1 is corrected on Figure D-1a. The sediment conductivity results of transects 1, 2, and 8 (figures D-1, D-2, and D-5) indicated that the central part of Parrotts Bay consists of soft sediments. The sediment conductivity can be considered as high (range 900 to 1100 μS/cm) which potentially indicates the presence of con-taminants.

The area outside of Parrots Bay, south of Millhaven Fibres Ltd., consists mainly of a shallow nearshore area containing exposed bedrock and stones plus a deep offshore trench (depth more than 50 metres). The sediment conductivity is low in the nearshore area. Small anomalies can be seen near the outfall marked

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by a buoy (outfall pipe is marked by dashed line). A much smaller anomaly extending east of the outlet located west of Millhaven Fibres is also evident. The latter anomaly is not well defined because of the small number of transects; however its shape suggests the possible origin of the anomaly at the outlet.

The sediment conductivity in the deeper area is significantly higher, indicating a thicker layer of soft material on the bottom. There is one higher anomaly in this area, centered at 900 m N x 1000 m E (figure 3.8). This anomaly is also shown on the profile of line 3 (figure D-3). At the same time, point measurements in the vicinity of this part of line 3 confirm this feature. The hydrographic chart does not show any bottom depression in this place, and it is difficult to explain the nature of this anomaly. It is concluded that the sediment conductivity increases with depth in the trench, where the sedimentation activity is naturally higher than in the shallower areas. The sparse placement of the measurement points (continuous profiling was not possible) does not allow more detailed variations in this area to be observed.

The bottom water conductivity and temperature color maps show a significant change between readings taken during the first and second survey days. The boundary can be seen at approximately 1000 m N in figures 3.9 and 3.10. If this difference was present only on the temperature map, the water column conditions could be considered as a source of this variation. The most probable origin is damaged cable interfacing temperature and water conductivity sensors (the electromagnetic instrument is interfaced by a separate cable) at the end of the profile line 1, early in the first survey day. At that time the instrument

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was stranded on a rock (it is shown on the hydrographic chart) and the cable was threadbare, but not cut. The cable was fixed on the boat; later during the evening this repair was examined and redone, and the cable was recalibrated. Assuming this fact the temperature taken during the second day of the survey should be considered as accurate, it is concluded that the inshore (shallower) bottom water temperature was lower than given on the temperature map (figure 3.10). The map of the measured water conductivity (without the temperature correction) is given in figure 3.9a. It shows that the true water conductivity readings taken during the first day of the survey are lower than suggested from temperature correction.

As done with the Cataraqui Bay survey, the map of the sediment conductivity without the temperature correction is given in figure 3.8a. The distribution of the sediment electrical conductivity is similar to the one on figure 3.8 (with the temperature correction) with a slightly enhanced dynamic range.

Comparing temperature-corrected and uncorrected maps, it can be seen that the sediment anomaly discussed above (900N X 1000E) now duplicates a small area of the elevated measured water conductivity. This observation suggests an area of groundwater seepage; however, more transects should be surveyed to confirm this hypothesis.
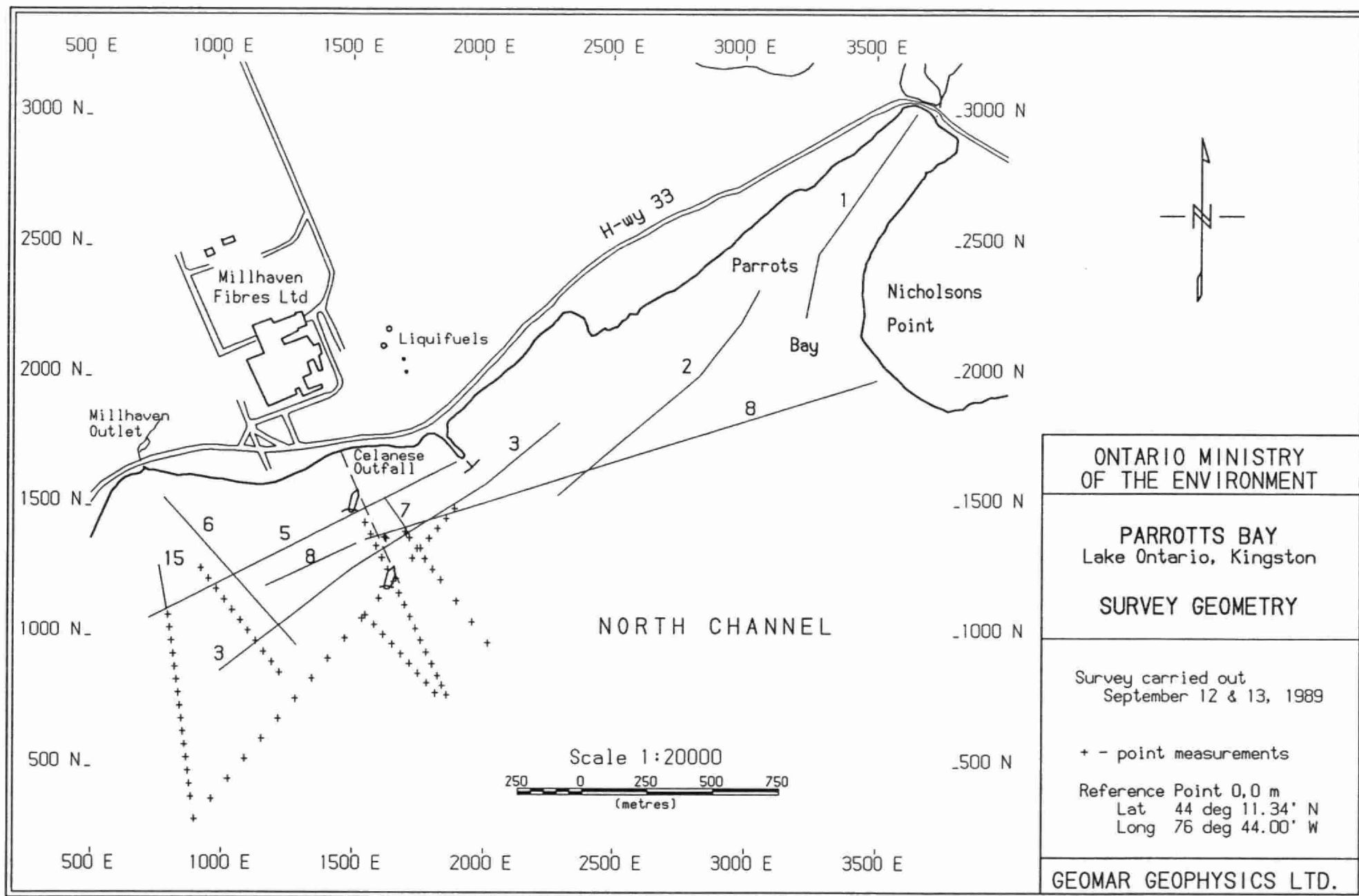
Figure 3.7
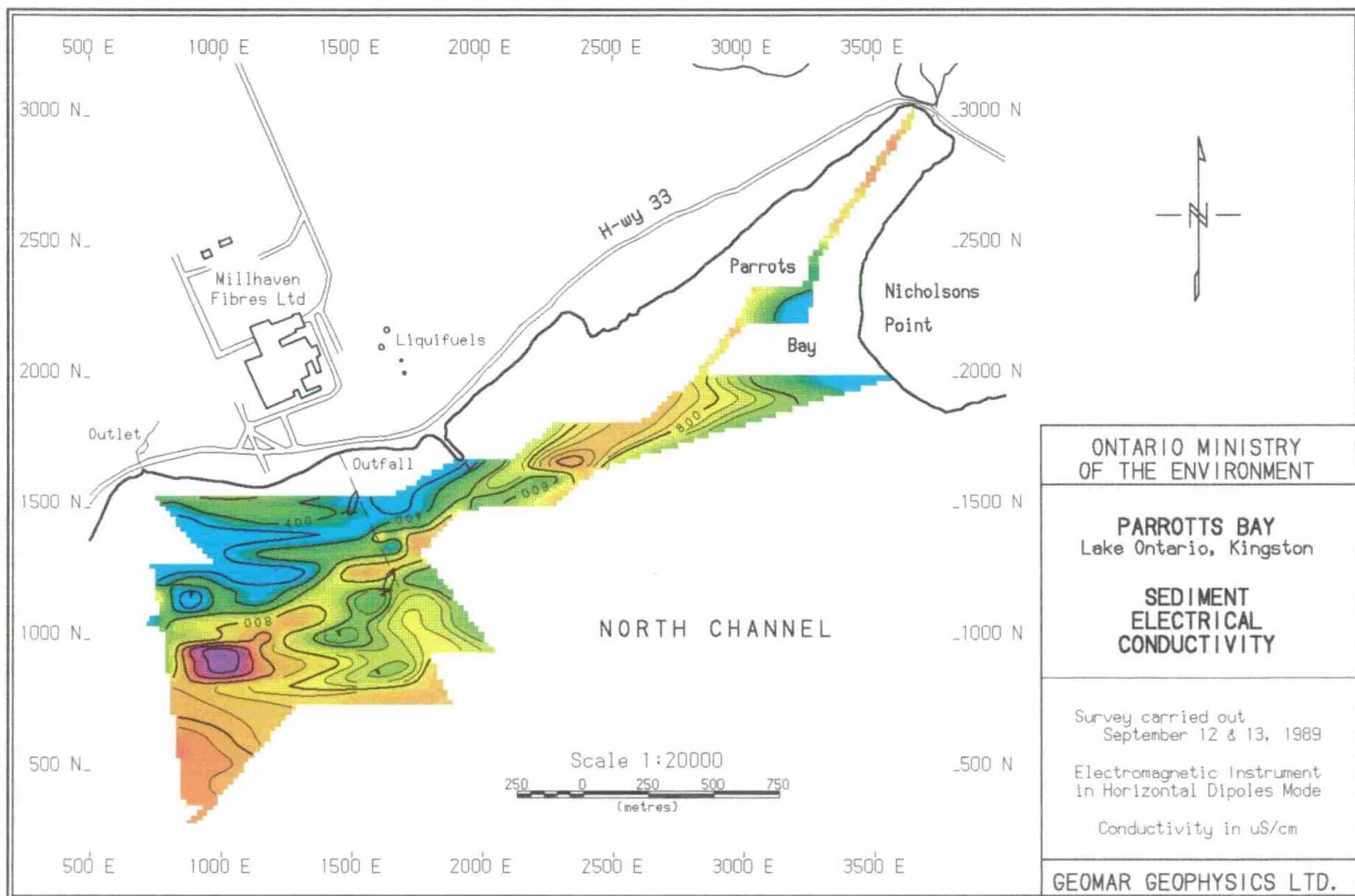
Figure 3.8
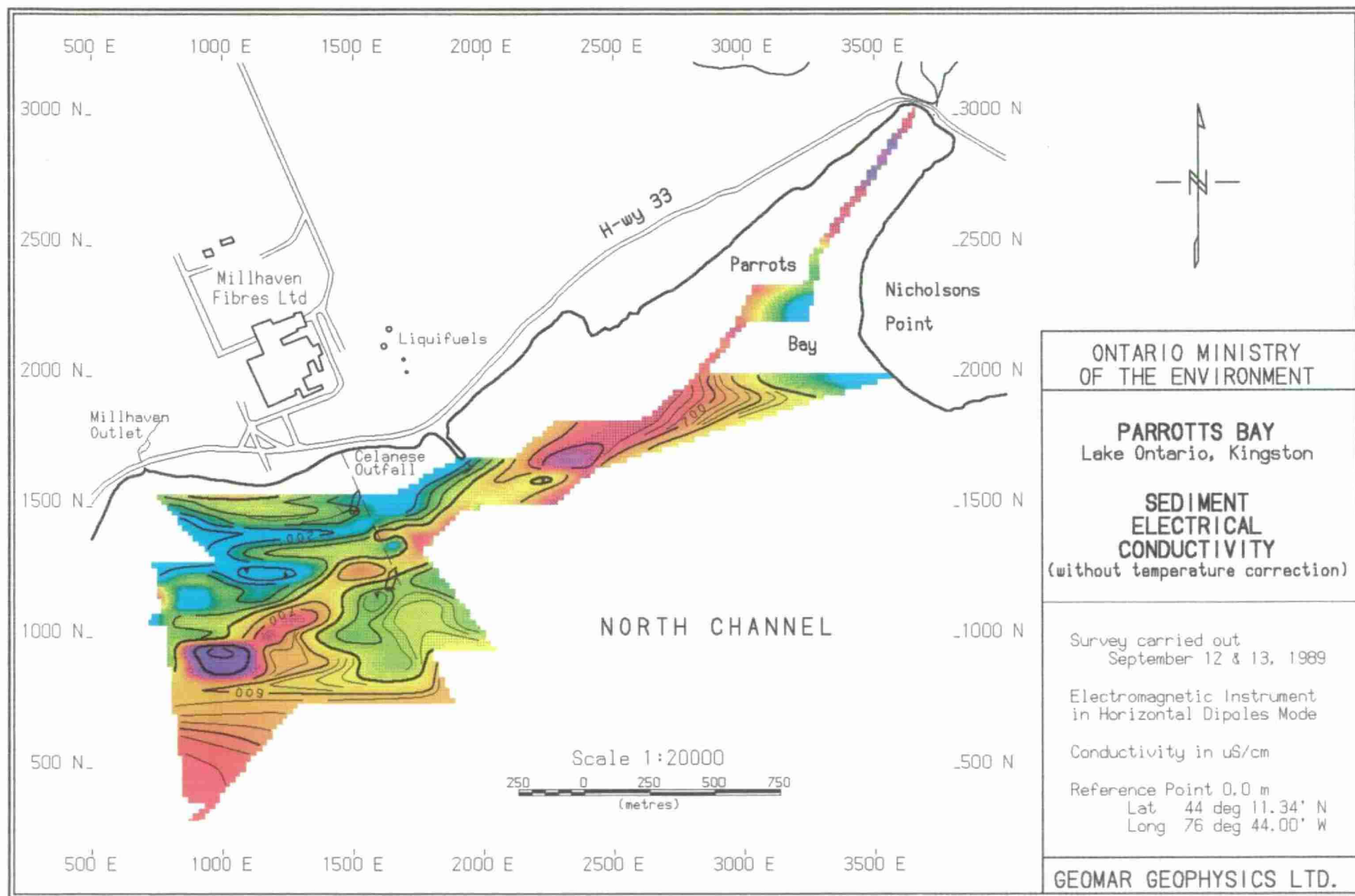
Figure 3.8a

Figure 3.9

Figure 3.9a

Map content (labels):

500 E · 1000 E · 1500 E · 2000 E · 2500 E · 3000 E · 3500 E

3000 N · 2500 N · 2000 N · 1500 N · 1000 N · 500 N

H-wy 33

Millhaven Fibres Ltd

Liquifuels

Millhaven Outlet

Celanese Outfall

Parrots

Bay

Nicholsons Point

NORTH CHANNEL

Scale 1:20000

250   0   250   500   750
(metres)

N

ONTARIO MINISTRY OF THE ENVIRONMENT

PARROTTS BAY
Lake Ontario, Kingston

BOTTOM WATER ELECTRICAL CONDUCTIVITY
(without temperature correction)

Survey carried out
September 12 & 13, 1989

Electromagnetic Instrument in Horizontal Dipoles Mode

Water Conductivity in uS/cm

Reference Point 0.0 m
    Lat   44 deg 11.34' N
    Long 76 deg 44.00' W

GEOMAR GEOPHYSICS LTD.

ONTARIO MINISTRY
OF THE ENVIRONMENT

PARROTTS BAY
Lake Ontario, Kingston

BOTTOM WATER
TEMPERATURE

Survey carried out
September 12 & 13, 1989

Temperature in C degrees

GEOMAR GEOPHYSICS LTD.

Figure 3.10

4. FINAL DISCUSSION OF THE PROJECT

The electromagnetic sediment conductivity measurements were conducted in the Kingston area for the first time. The greatest difficulties were associated with the boat, which was too heavy and too fast. In addition, a longer cable for interfacing the instruments with the on-board data acquisition system would be desirable if the faster boat is to be used.

The results show that the method is very suitable in delineating anomalies in the sediment type and contamination, especially in very complex areas as Cataraqui Bay. The spacing between the transects should be finer to fully delineate small features. More profiles conducted within a particular area of interest would improve the resolution of the created maps. This could be done during the same survey if the data are plotted out in real time on an on-board computer. Such a system consisting of a laptop IBM PC compatible computer and analog to digital converter has already been developed by Geomar.

As discussed in the Geomar report for the Toronto Waterfront area, the relation between the sediment and water temperature should be better understood or the sediment temperature should be measured at a shallow depth eg. 0.25 to 0.5 m in at least few points. The work on the development of the sediment temperature probe is conducted by Geomar.

Much time was spent preparing profile plots. These plots are very suitable as a working tool during interpretation, but very laborious as a final presentation. In the future, beside contour maps, it would be useful to present only the most

important or interesting profile plots. Another time consuming part of the project was elaboration and reduction of the manually recorded navigation data. The easiest solution is to interface the navigation system with the on-board computer for automatic integration of the data. In addition, much better navigational accuracy could be achieved using a microwave positioning system.

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APPENDIX A
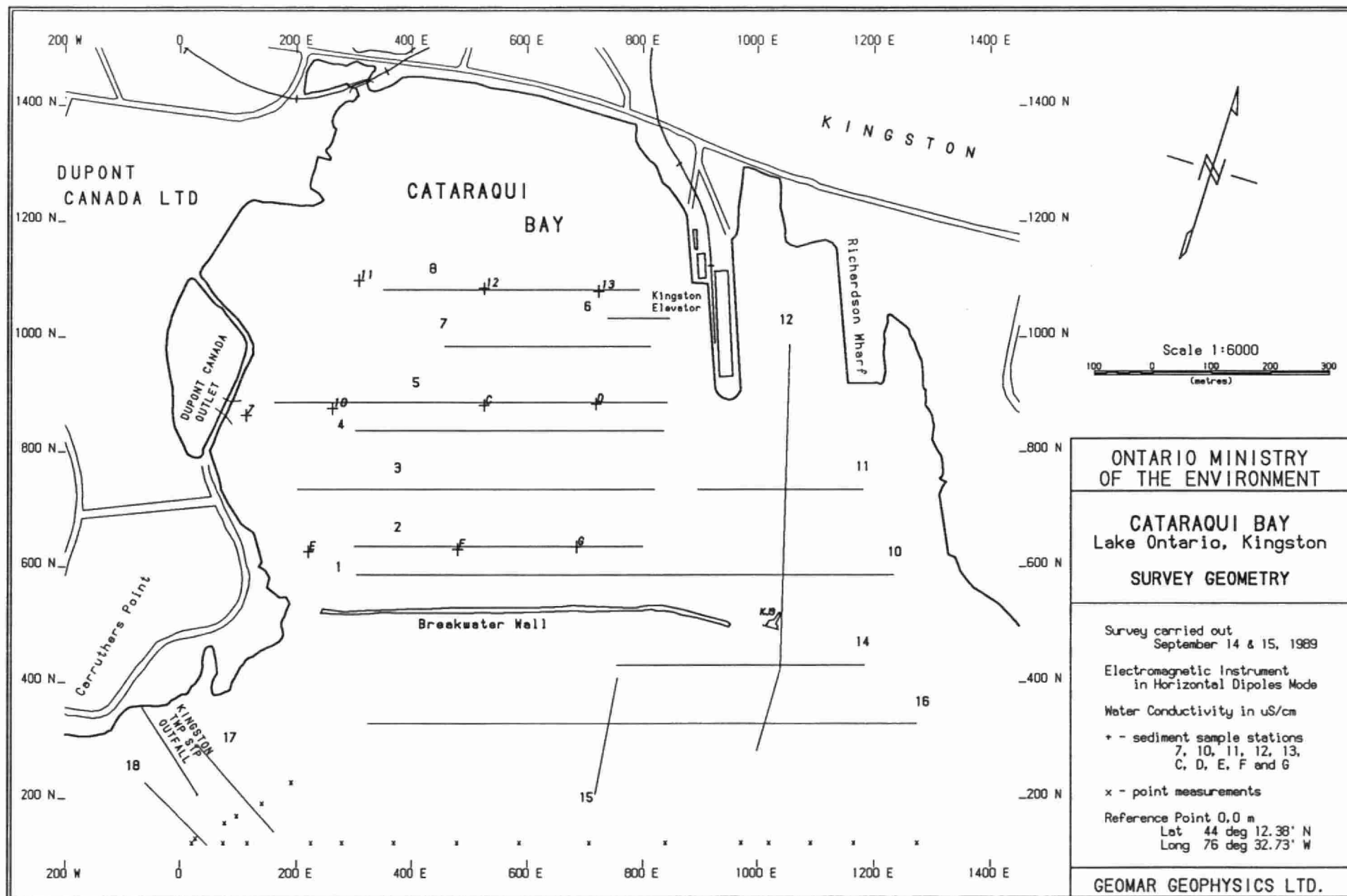
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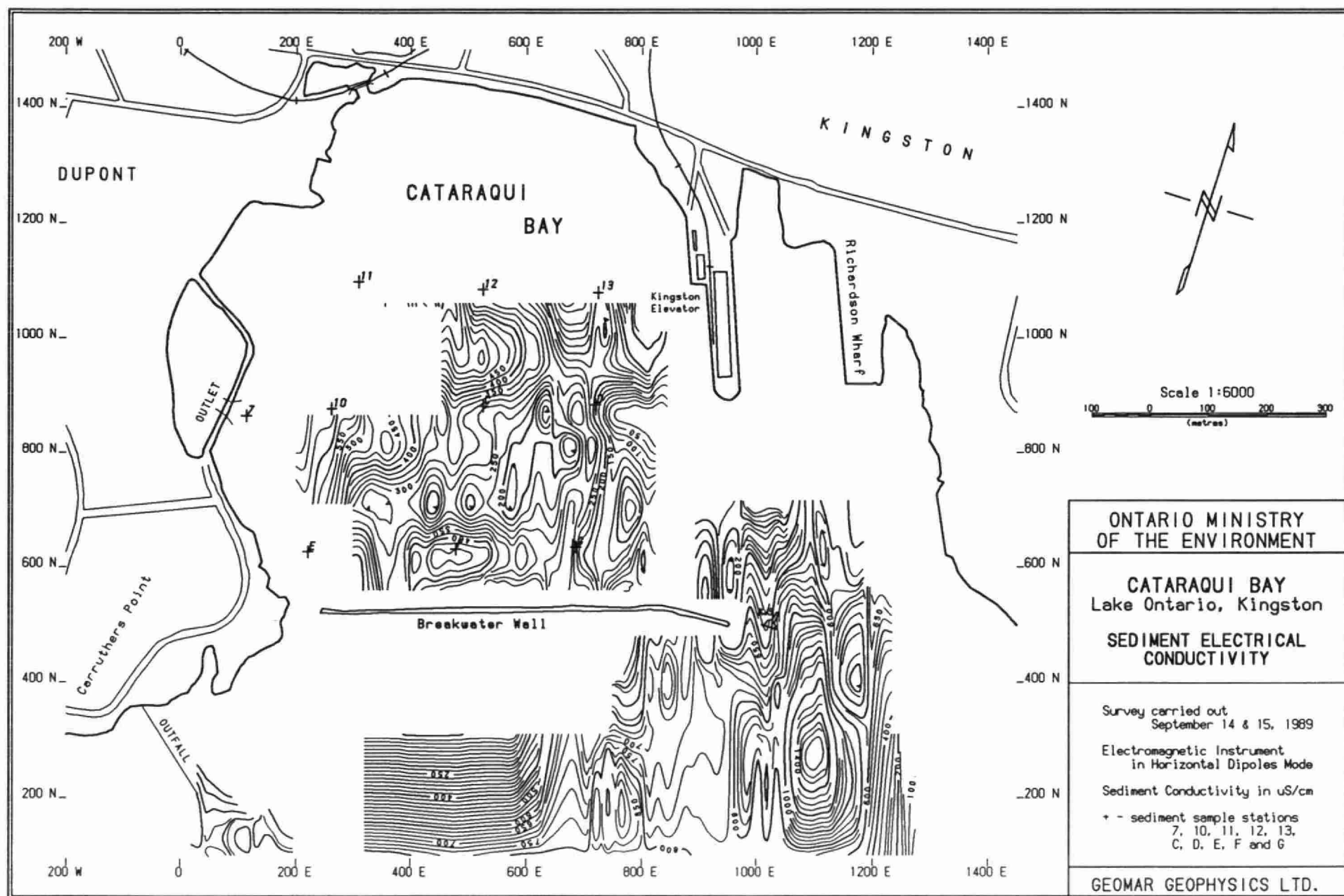
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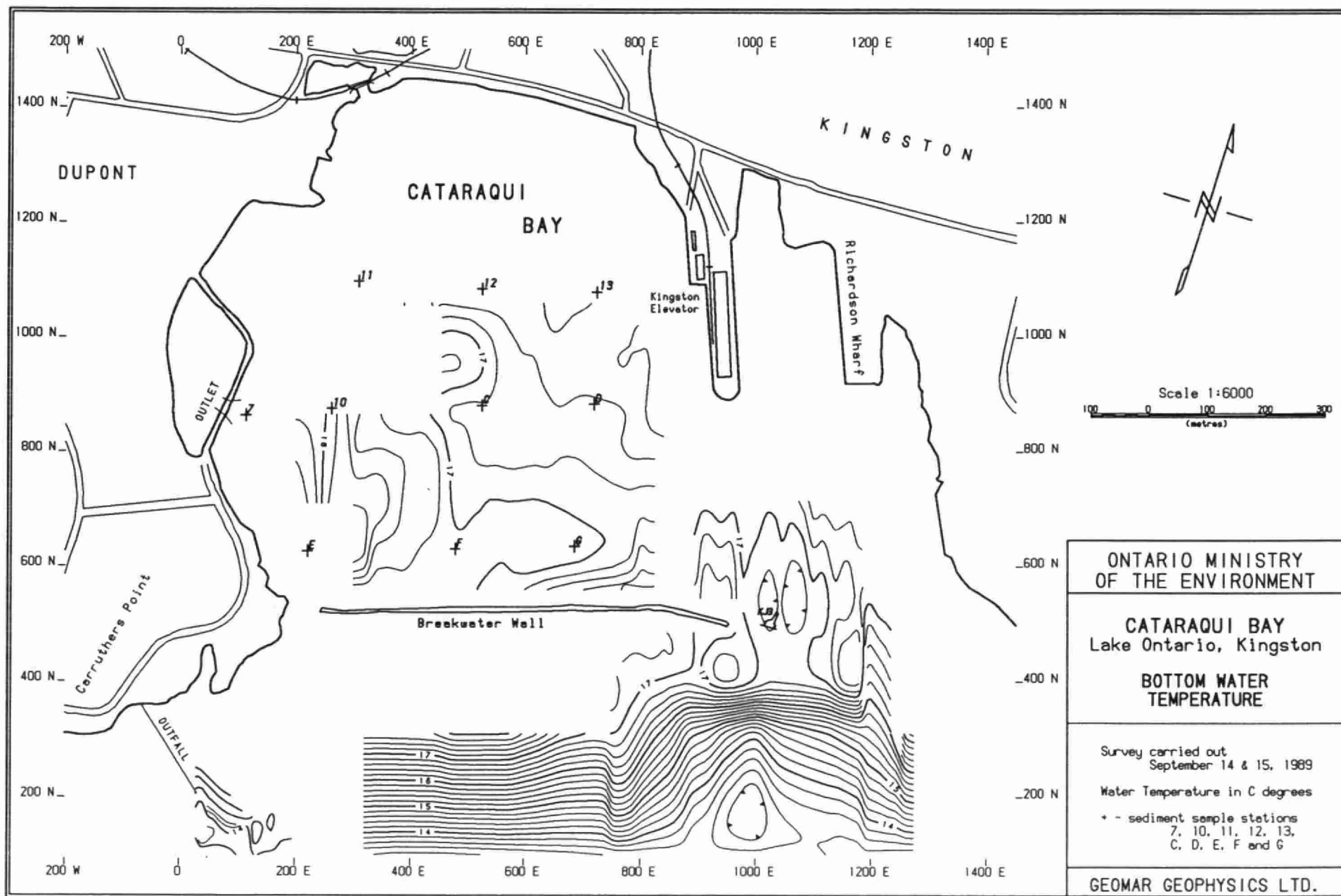
Figure A-3

Figure A-4

APPENDIX B
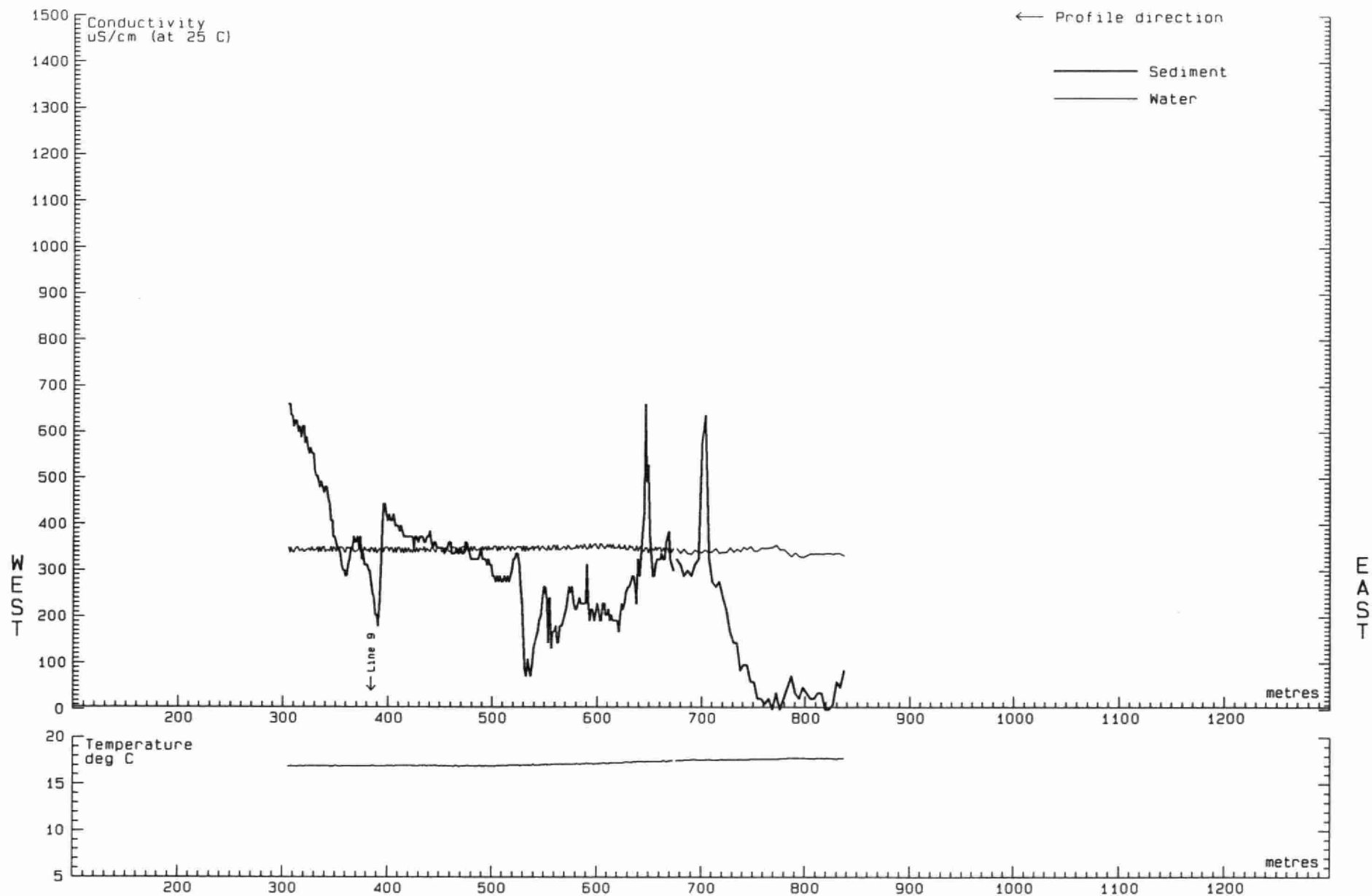
Fig. B-1   LINE 1   CATARAQUI BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode
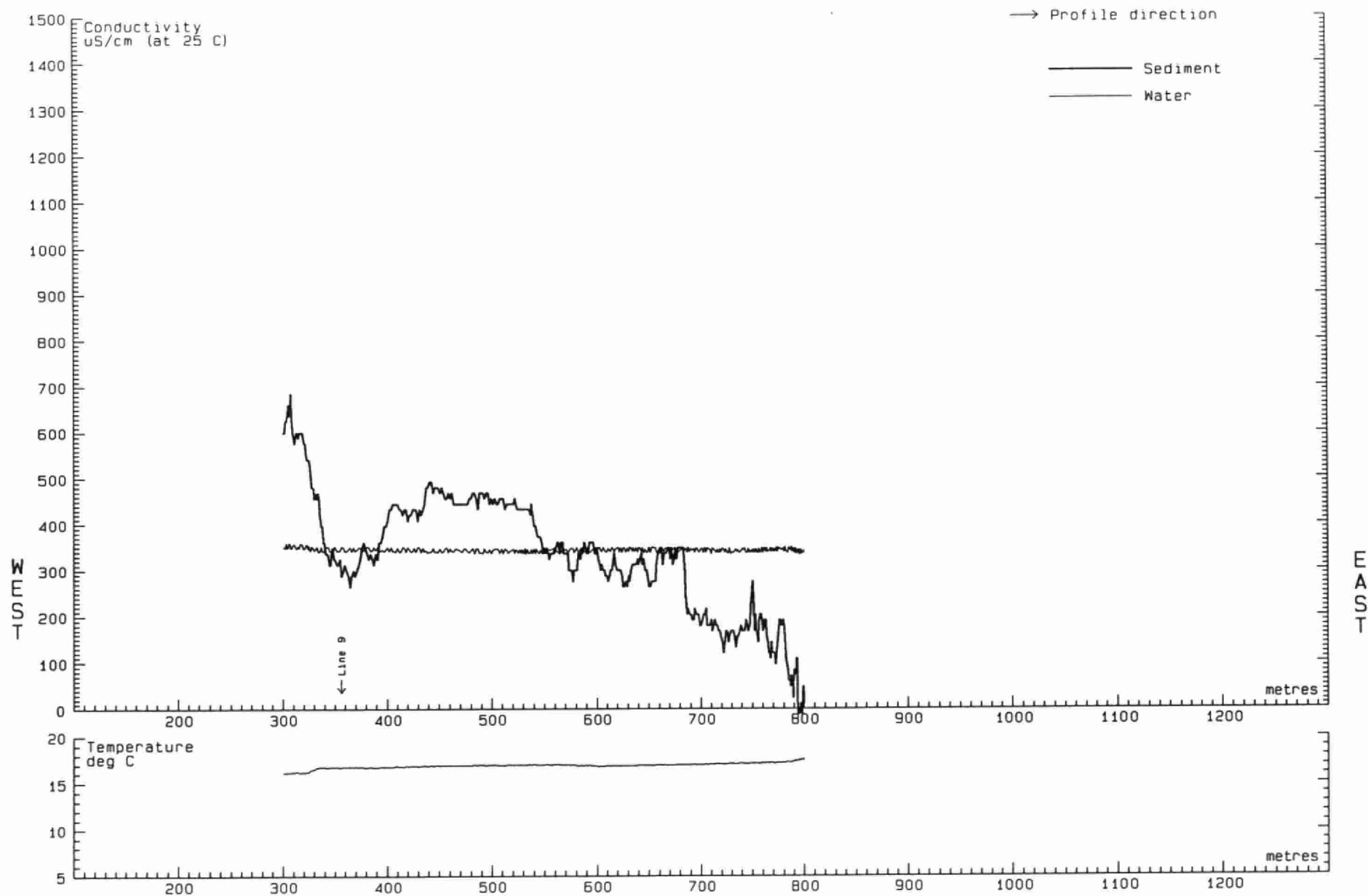
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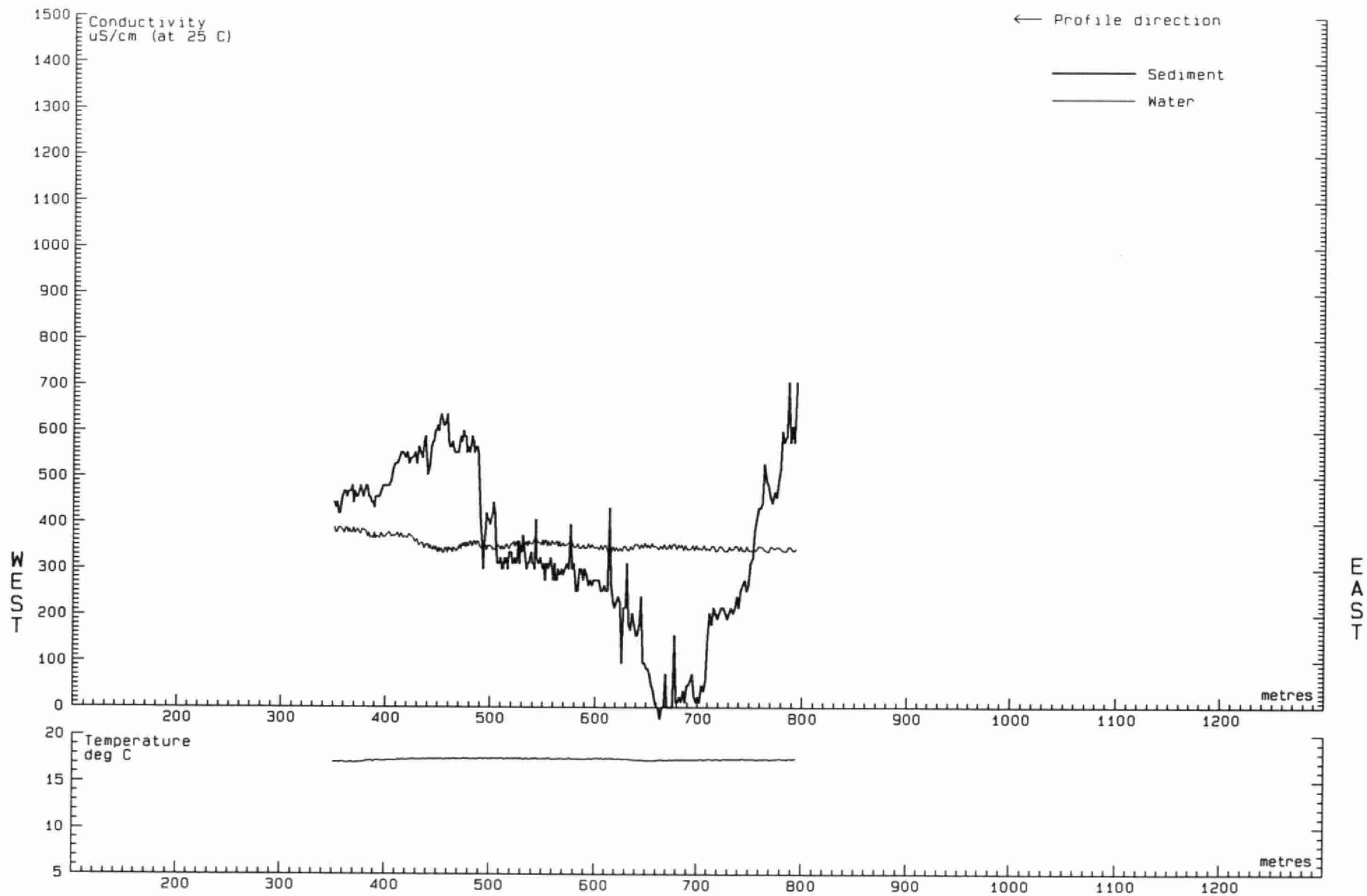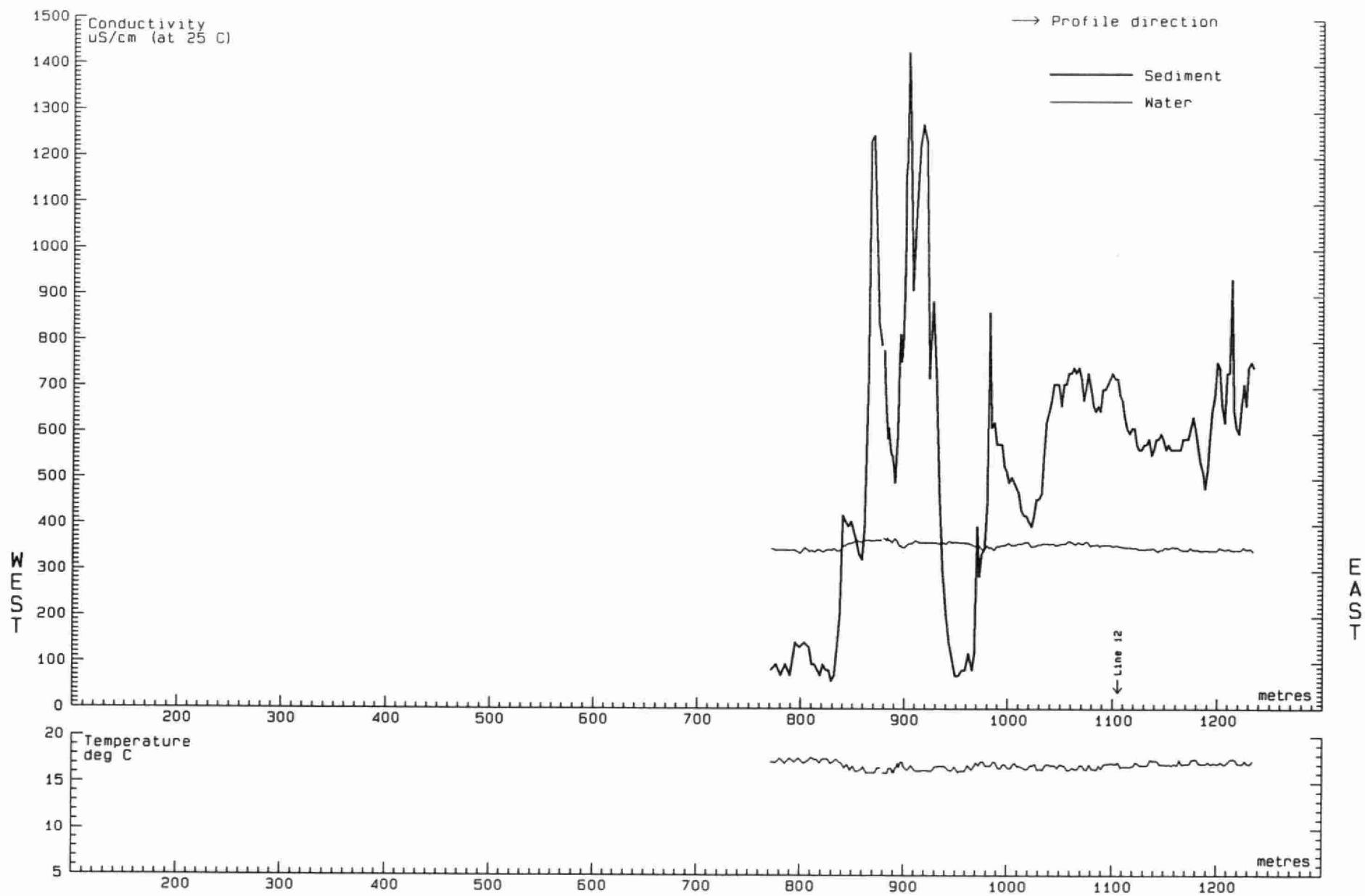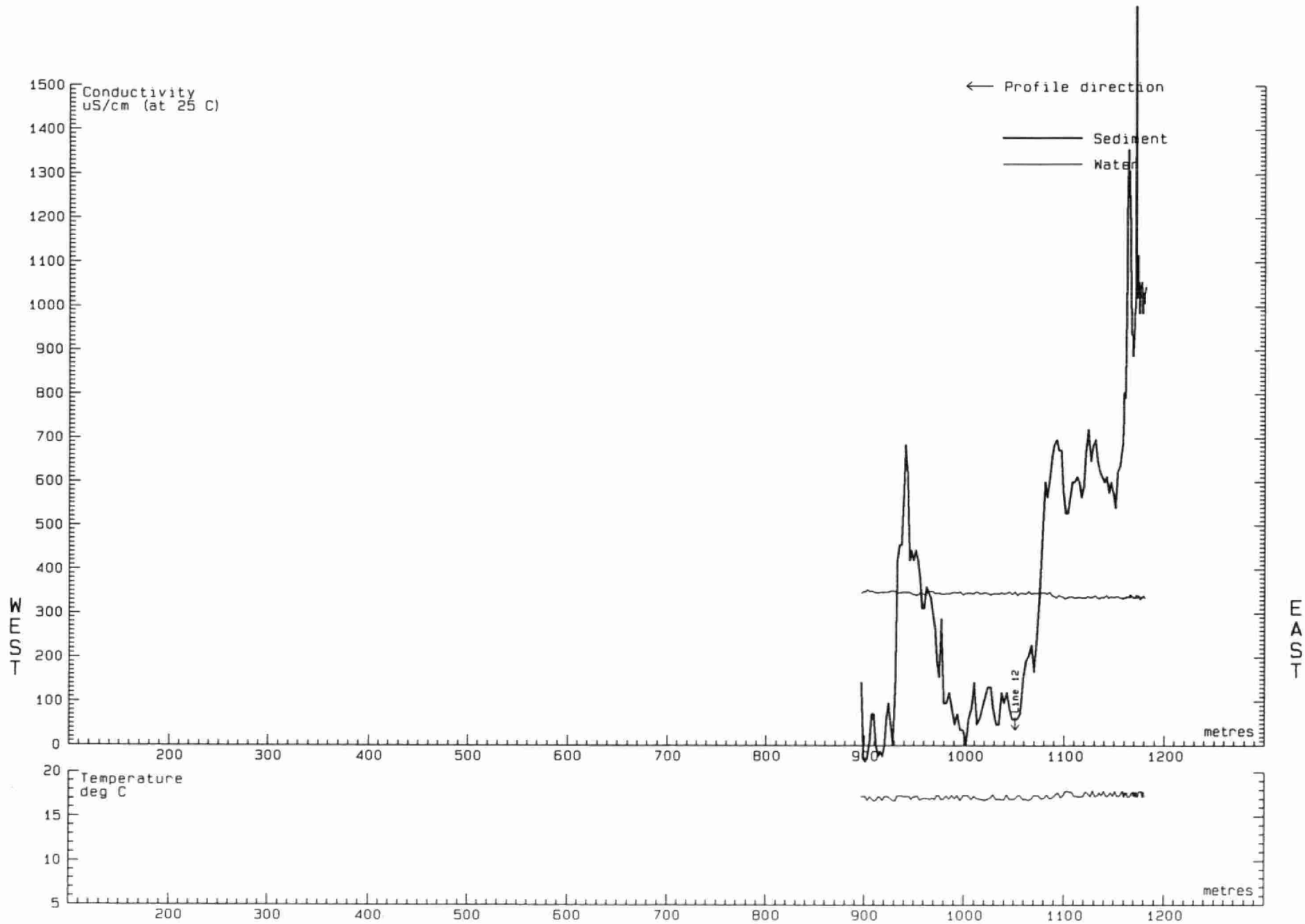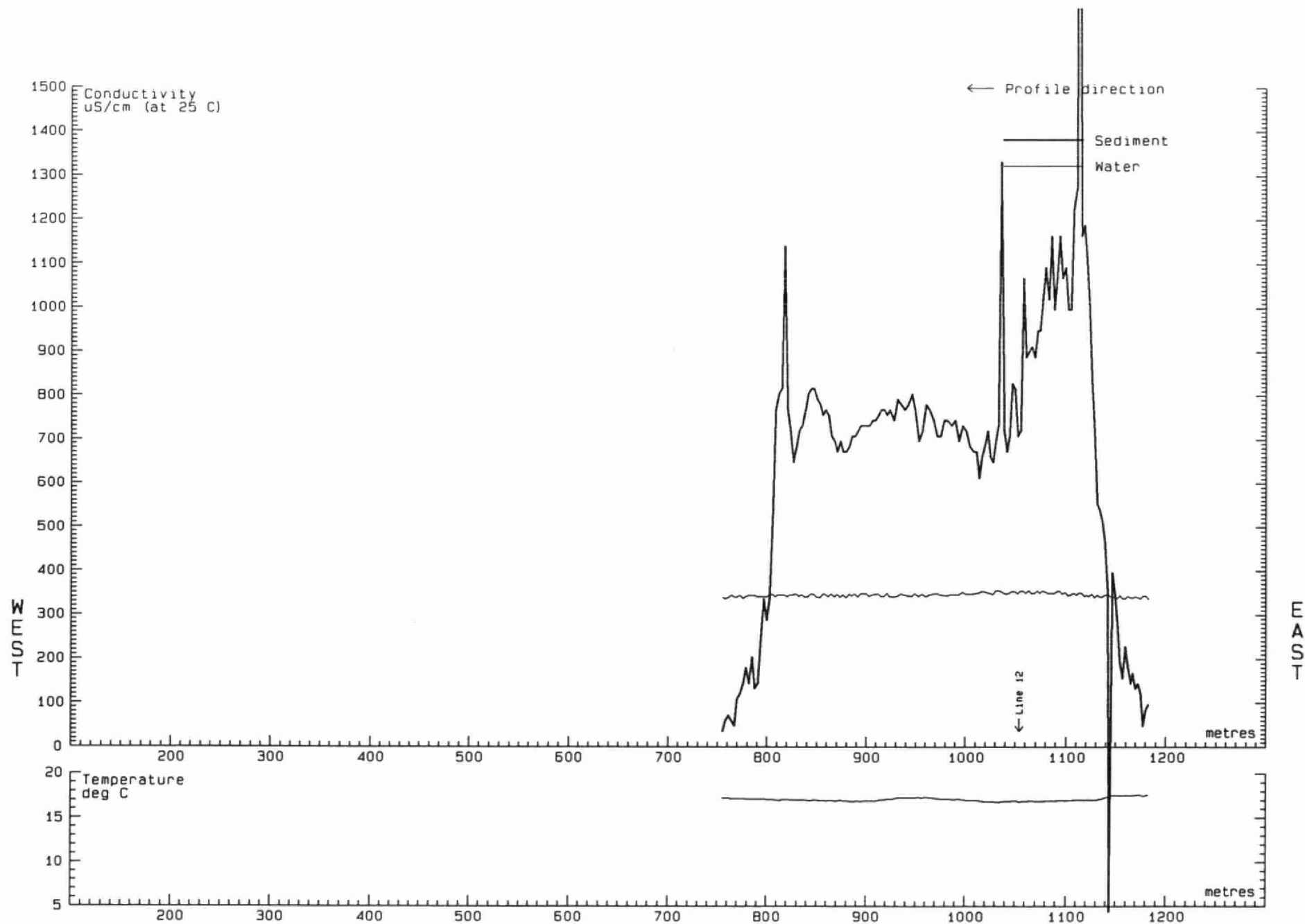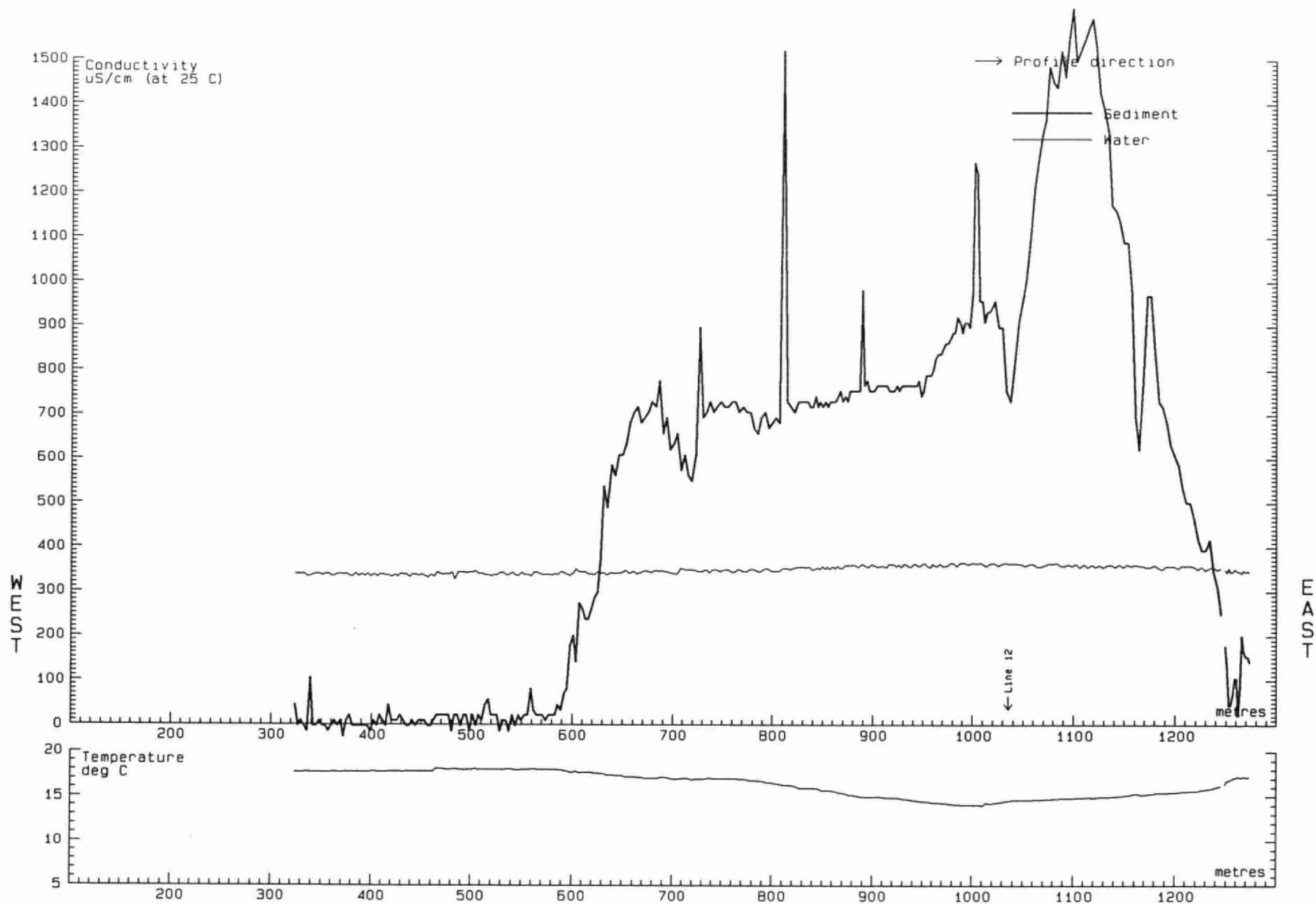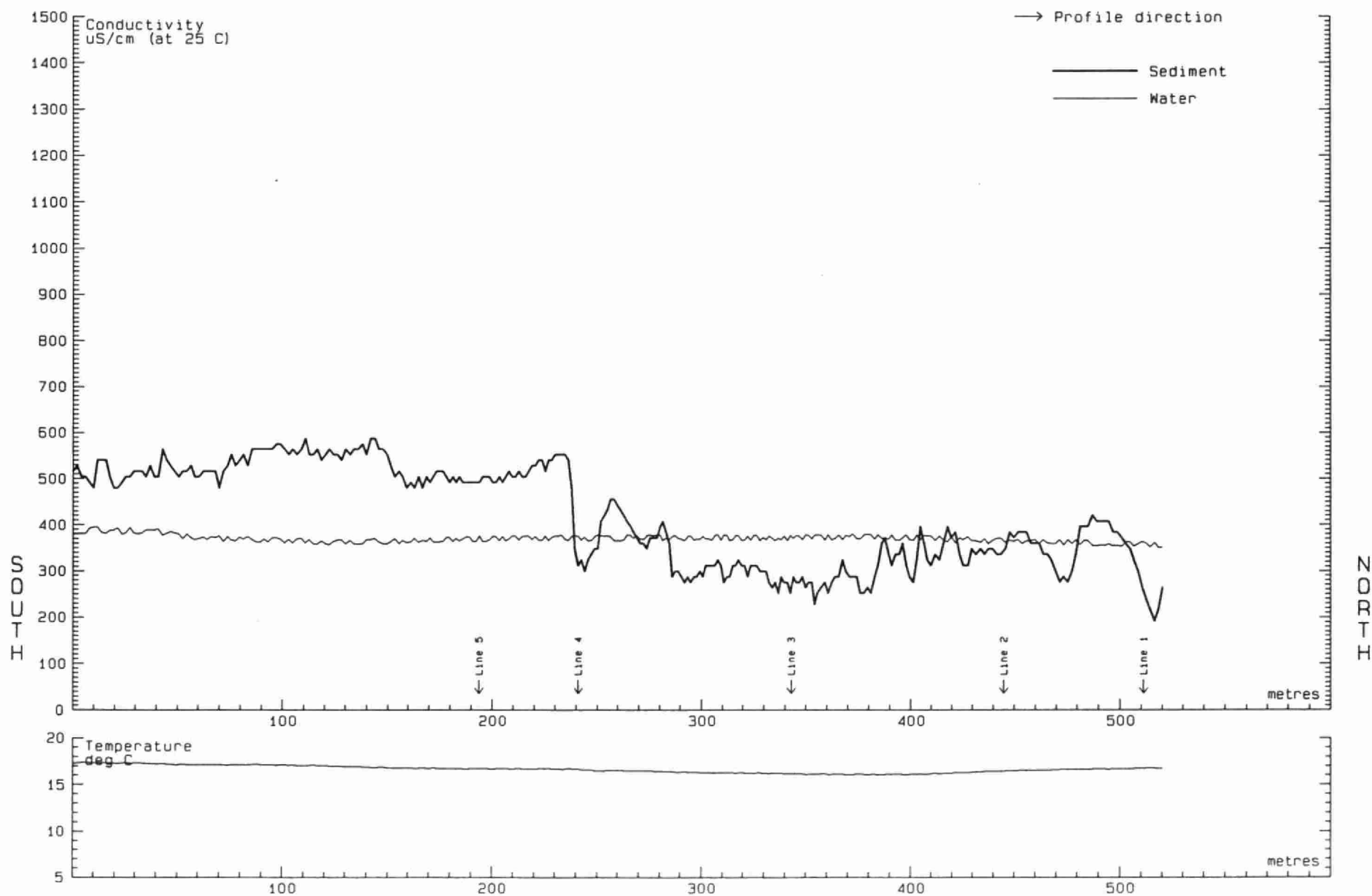Instrument in Horizontal Dipoles Mode
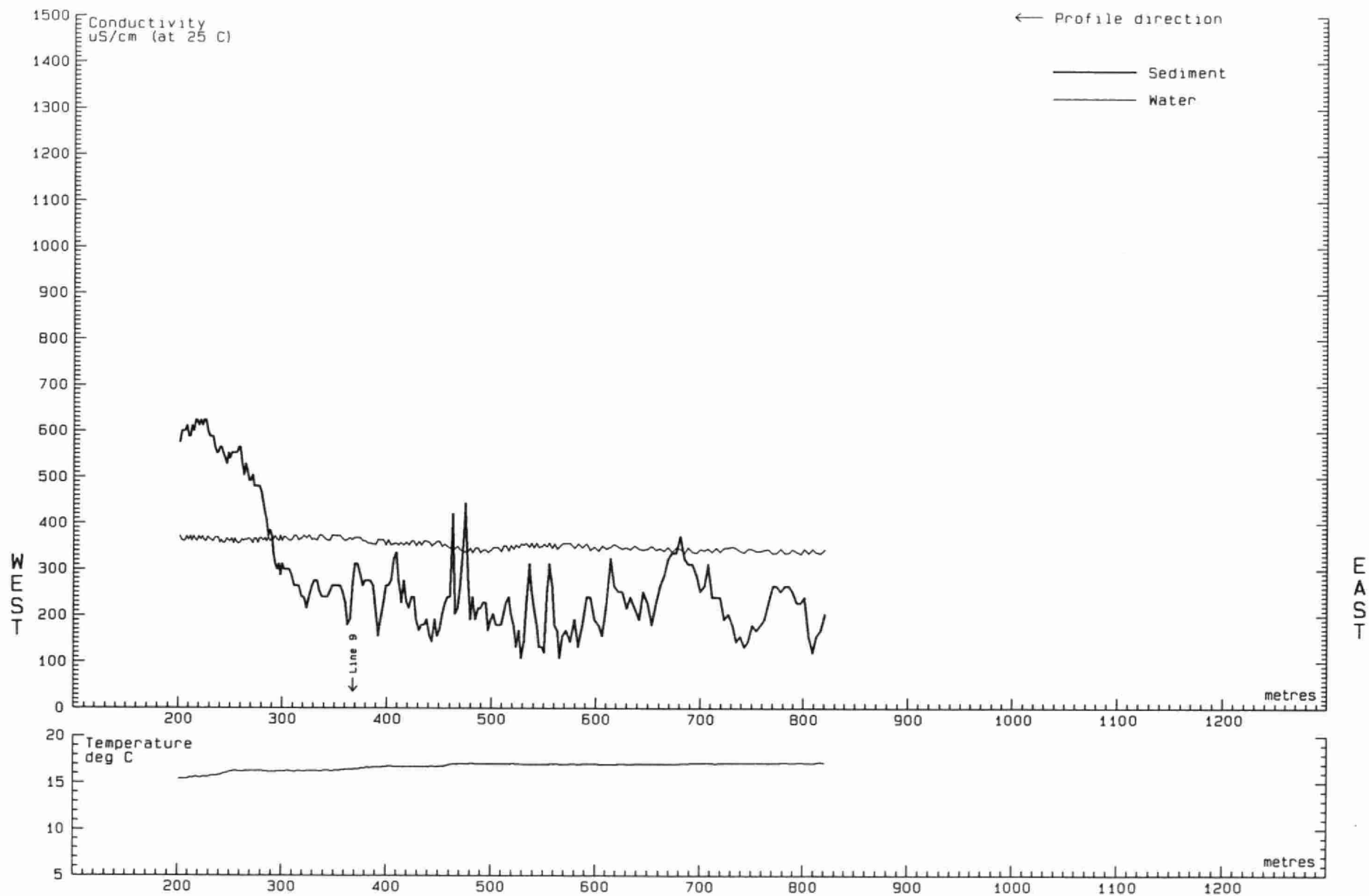
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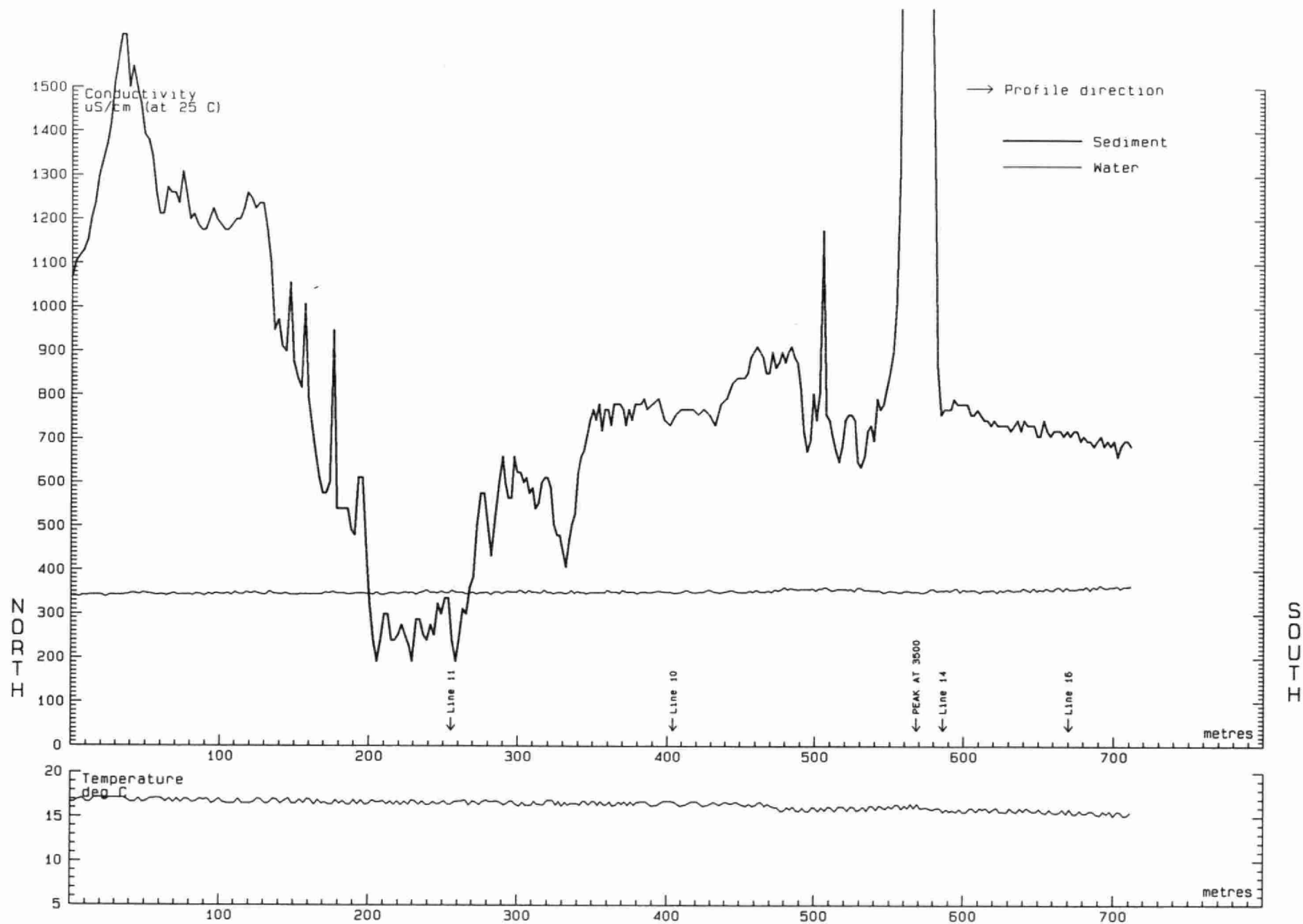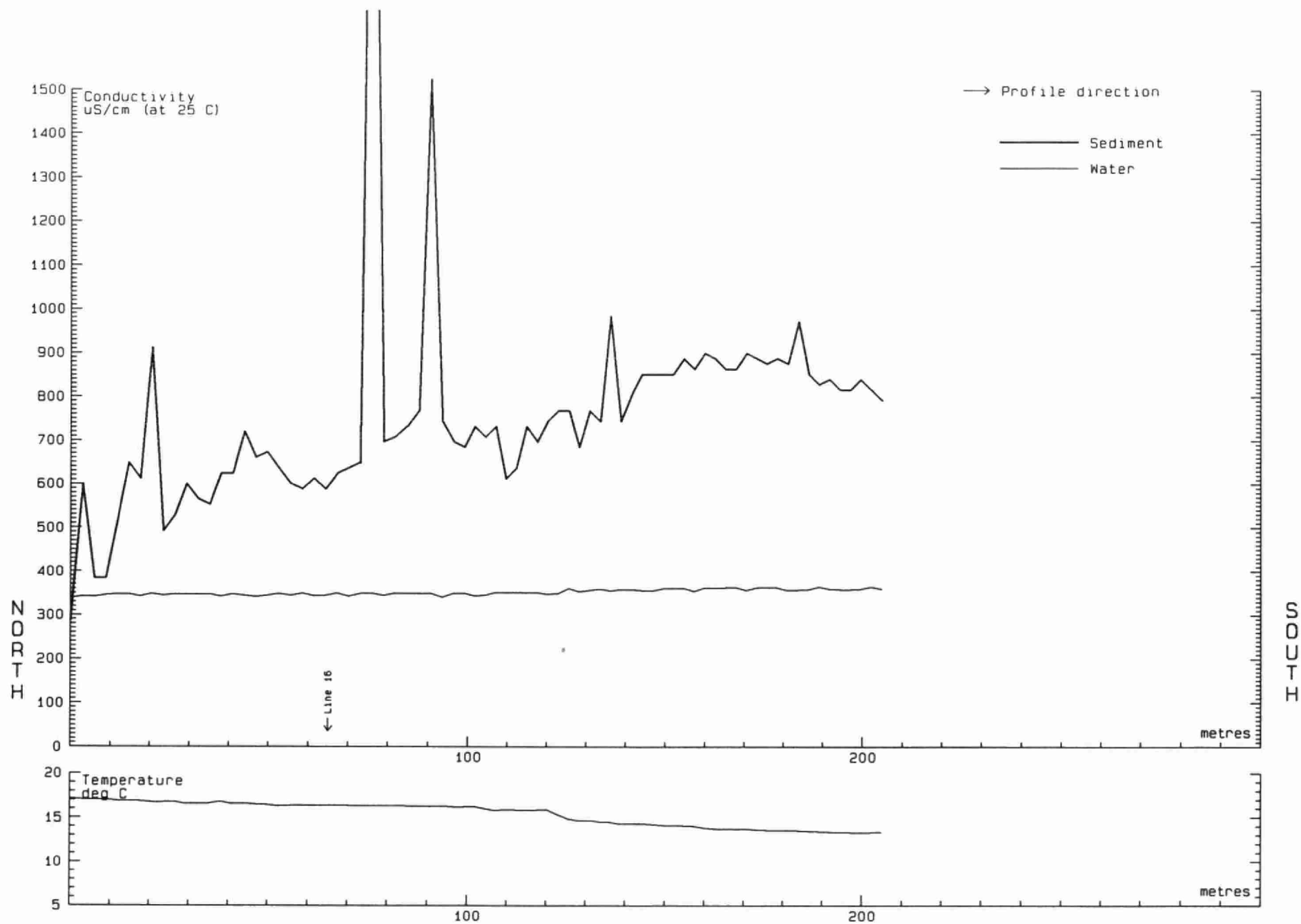Instrument in Horizontal Dipoles Mode
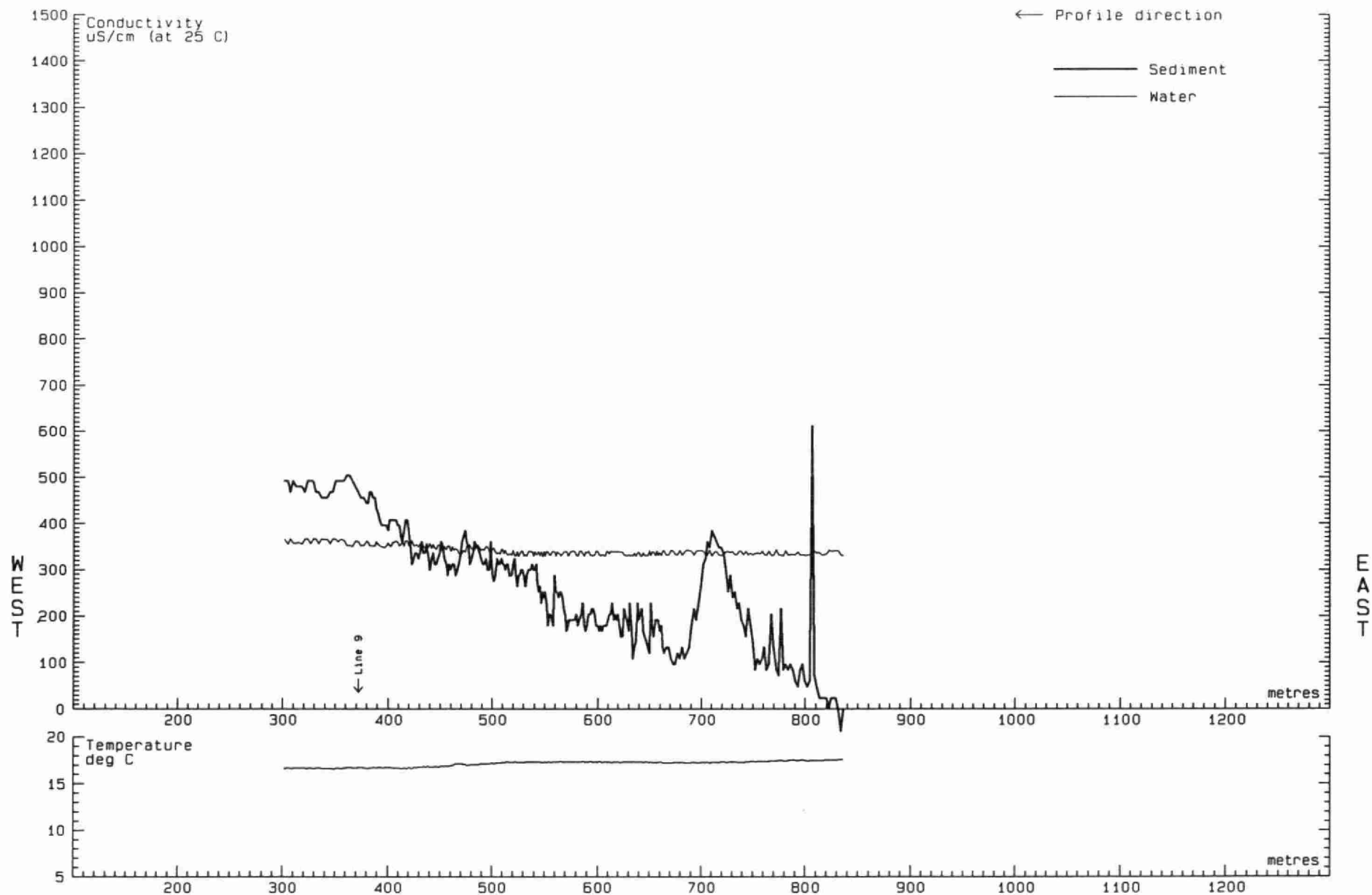
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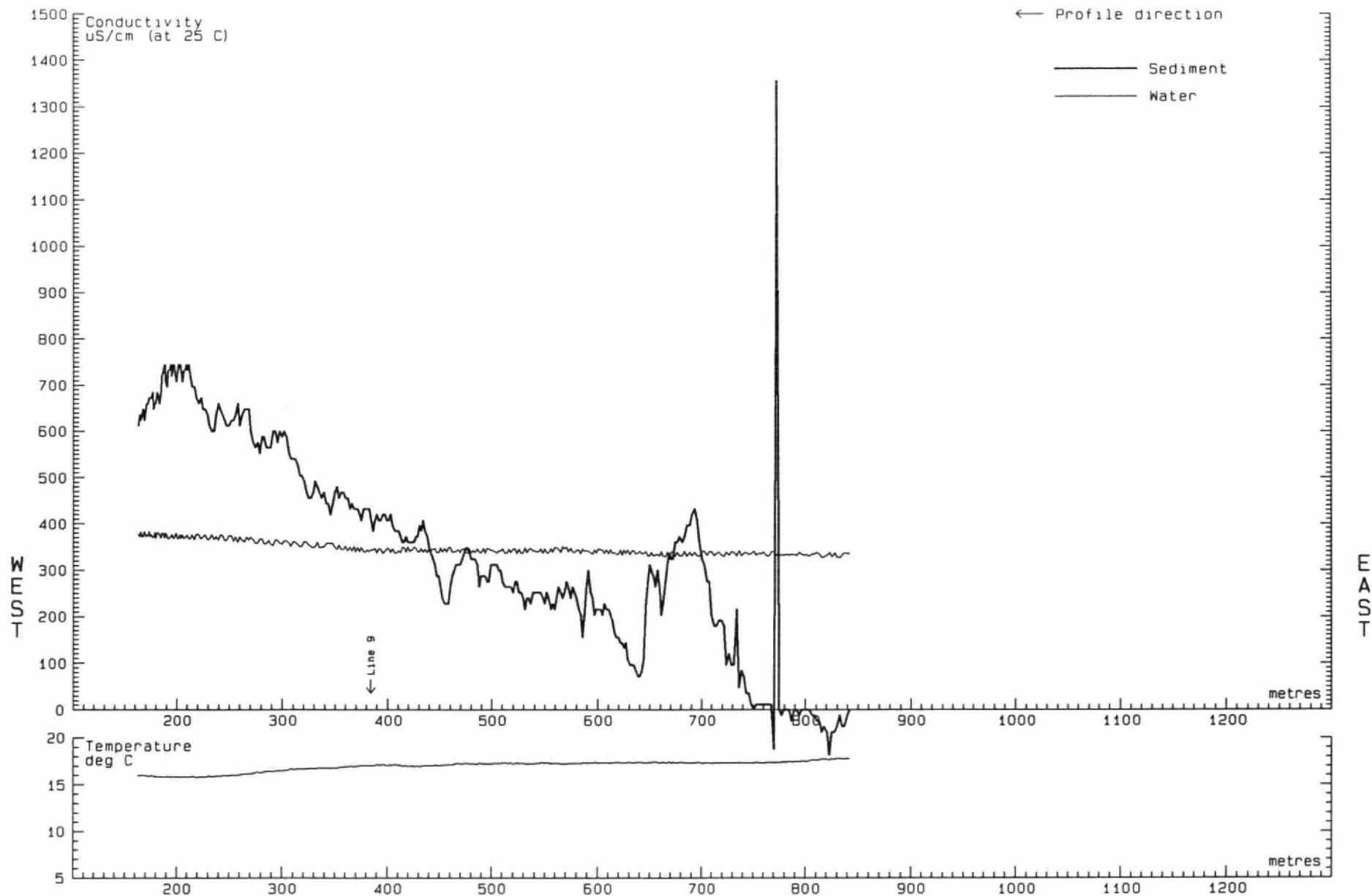
Fig. B-5   LINE 5   CATARAQUI BAY   SEPTEMBER 1989
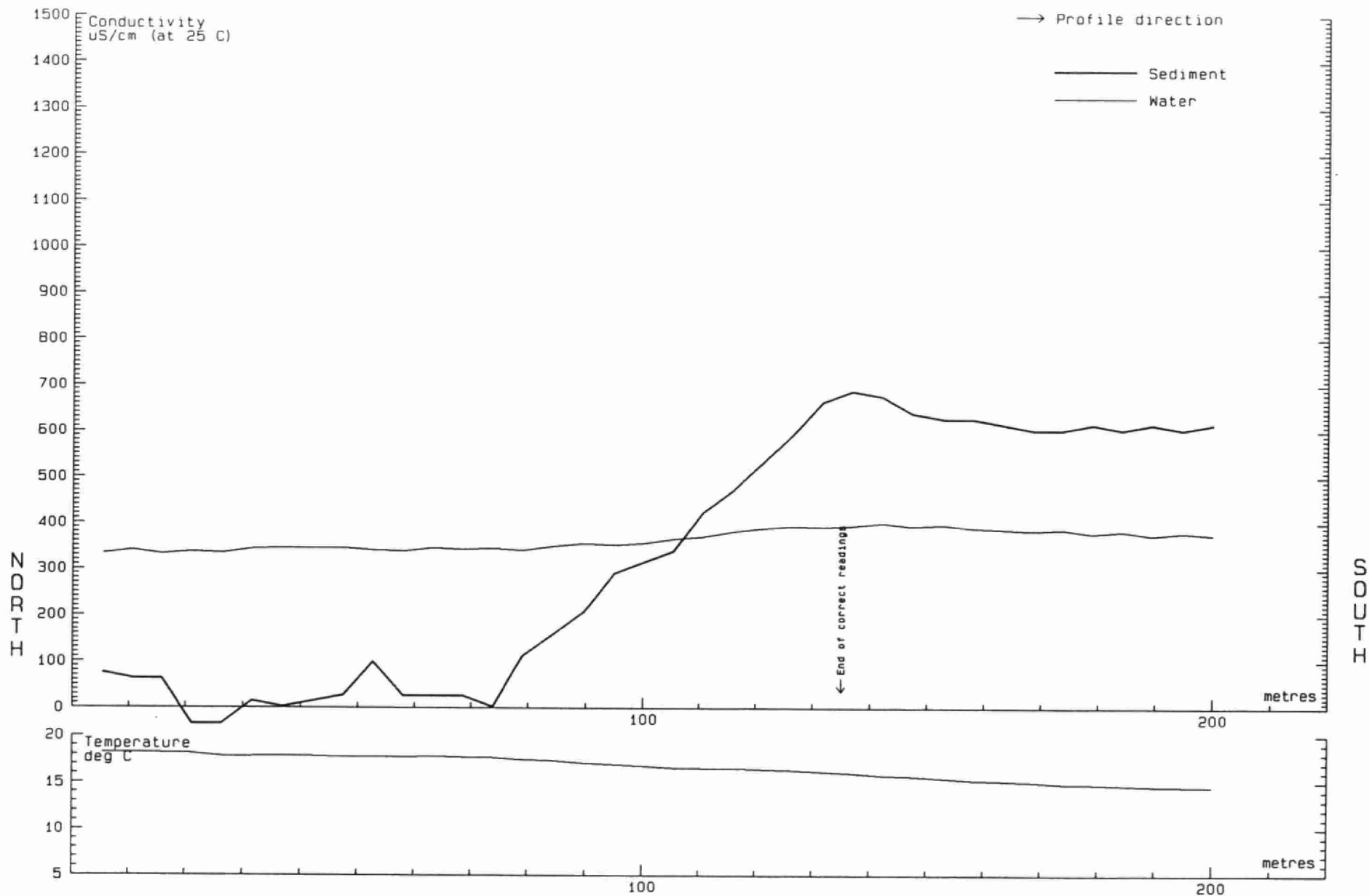Instrument in Horizontal Dipoles Mode
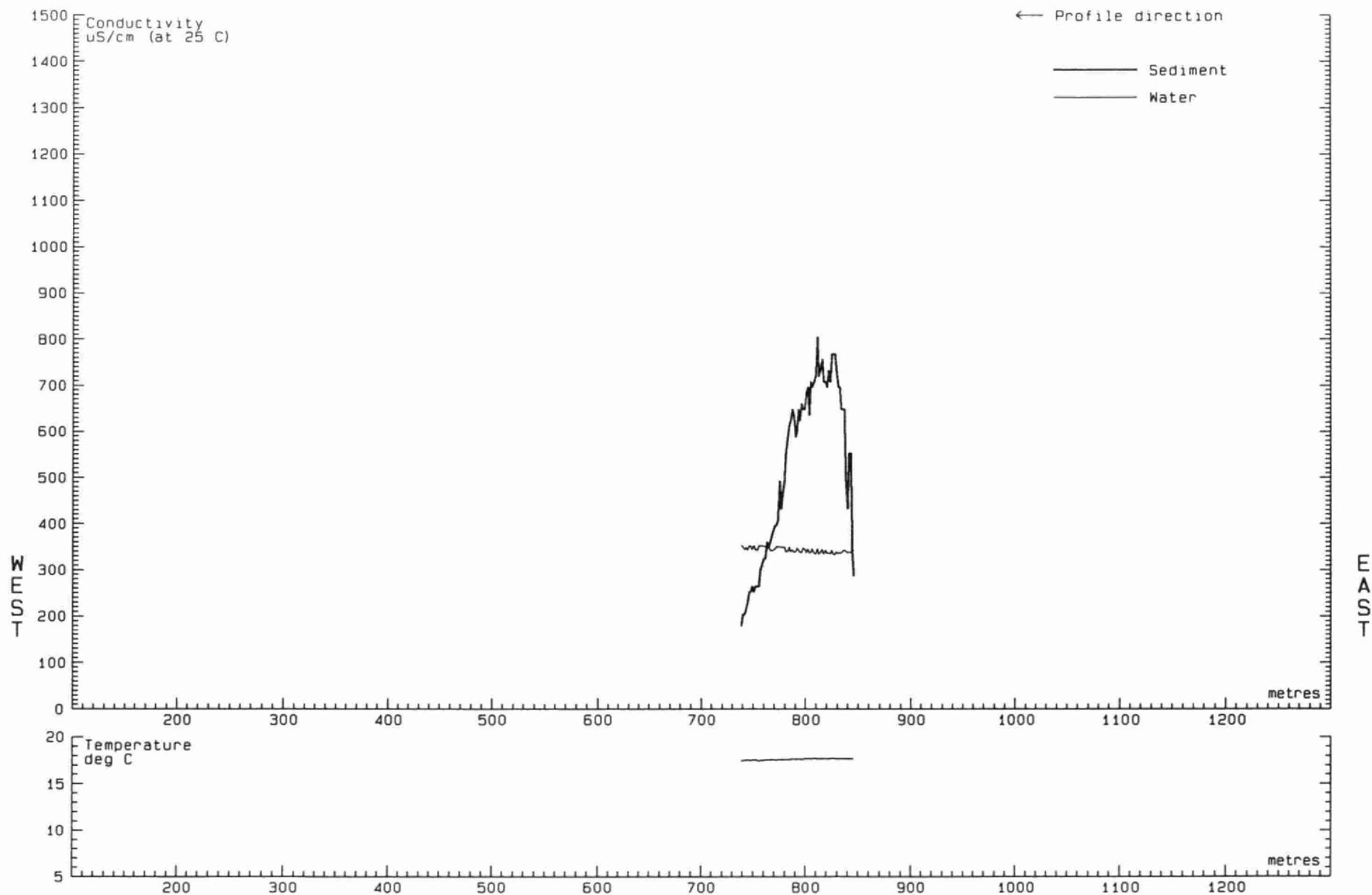
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Instrument in Horizontal Dipoles Mode
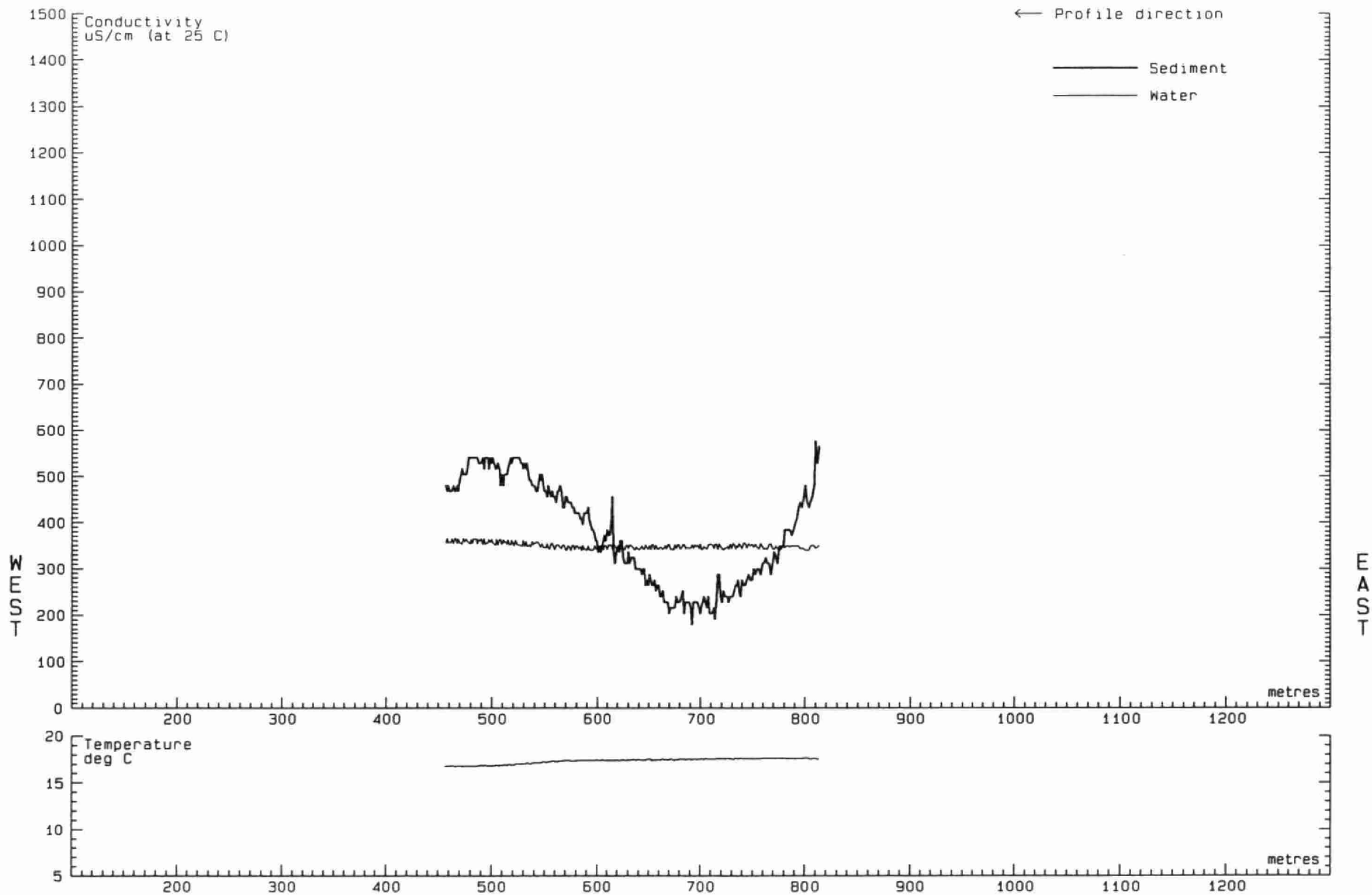
Fig. B-7   LINE 7   CATARAQUI BAY   SEPTEMBER 1989
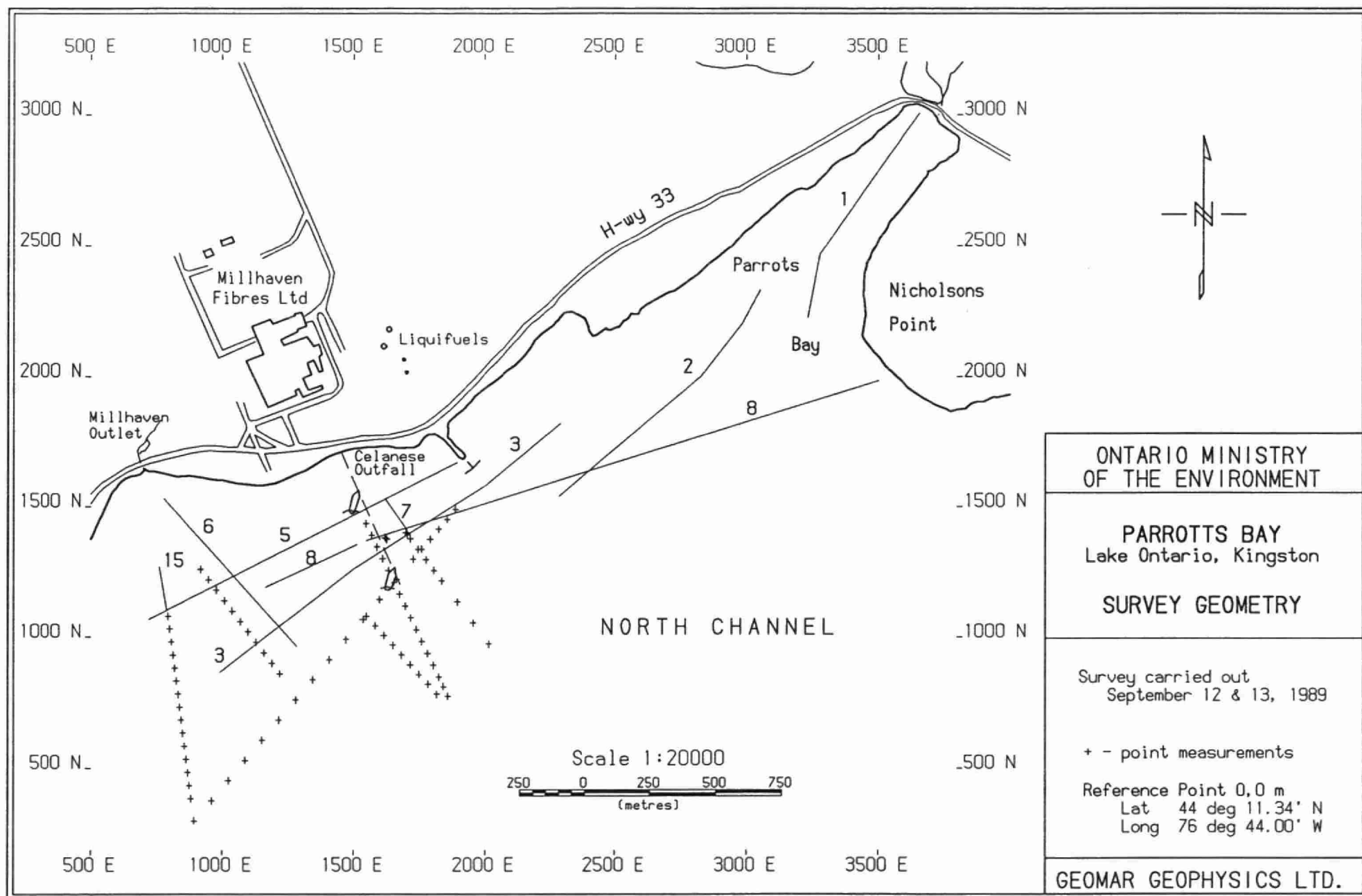Instrument in Horizontal Dipoles Mode

Fig. B-8   LINE 8   CATARAQUI BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

Fig. B-9   LINE 10   CATARAQUI BAY   SEPTEMBER 1989
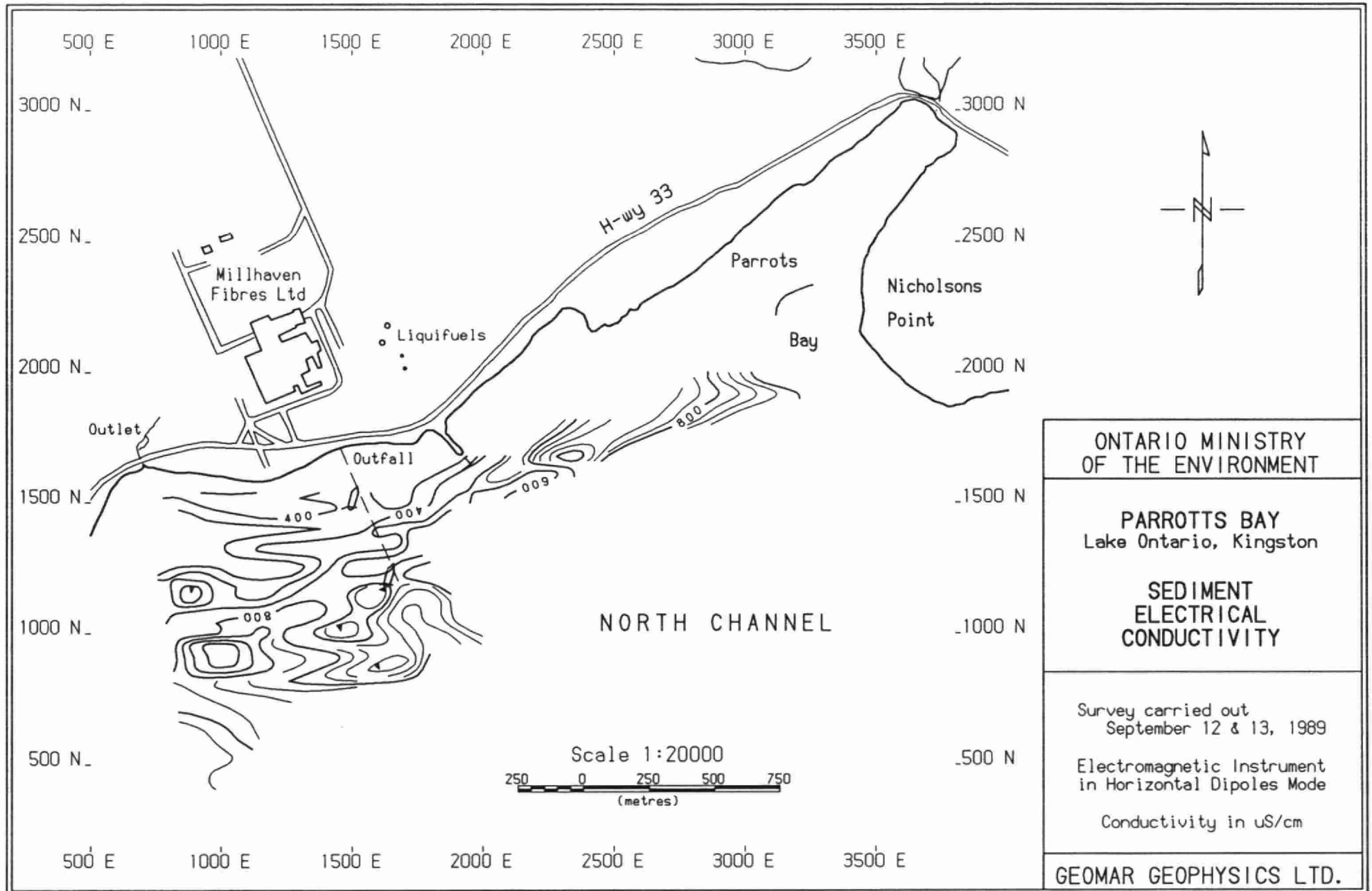Instrument in Horizontal Dipoles Mode

Fig. B-10   LINE 11   CATARAQUI BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

Fig. B-11   LINE 14   CATARAQUI BAY   SEPTEMBER 1989

Instrument in Horizontal Dipoles Mode

Fig. B-12.   LINE 16   CATARAQUI BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode
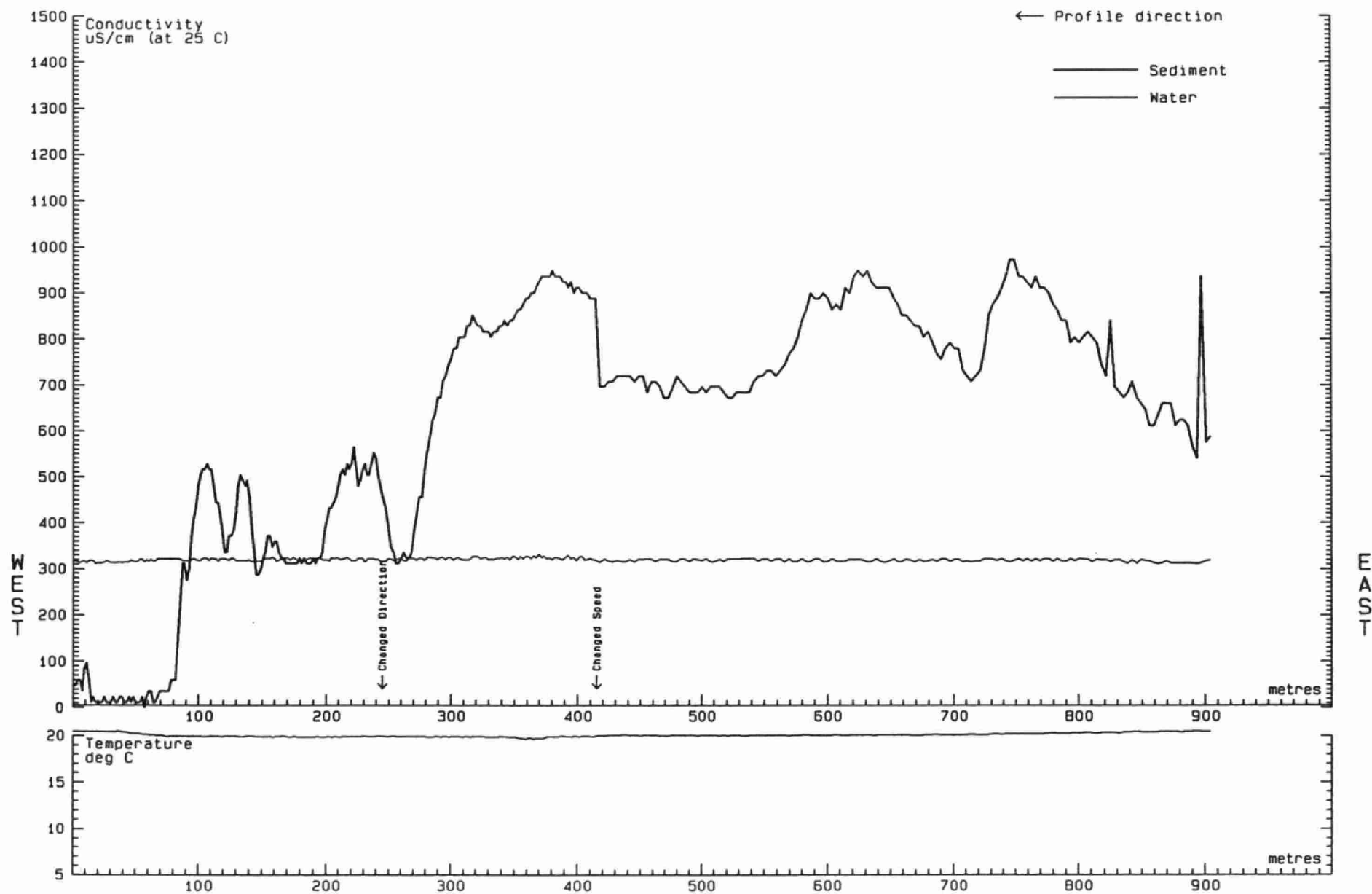
Fig. B-13   LINE 9   CATARAQUI BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

Fig. B-14   LINE 12   CATARAQUI BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

Fig. B-15   LINE 15   CATARAQUI BAY   SEPTEMBER 1989
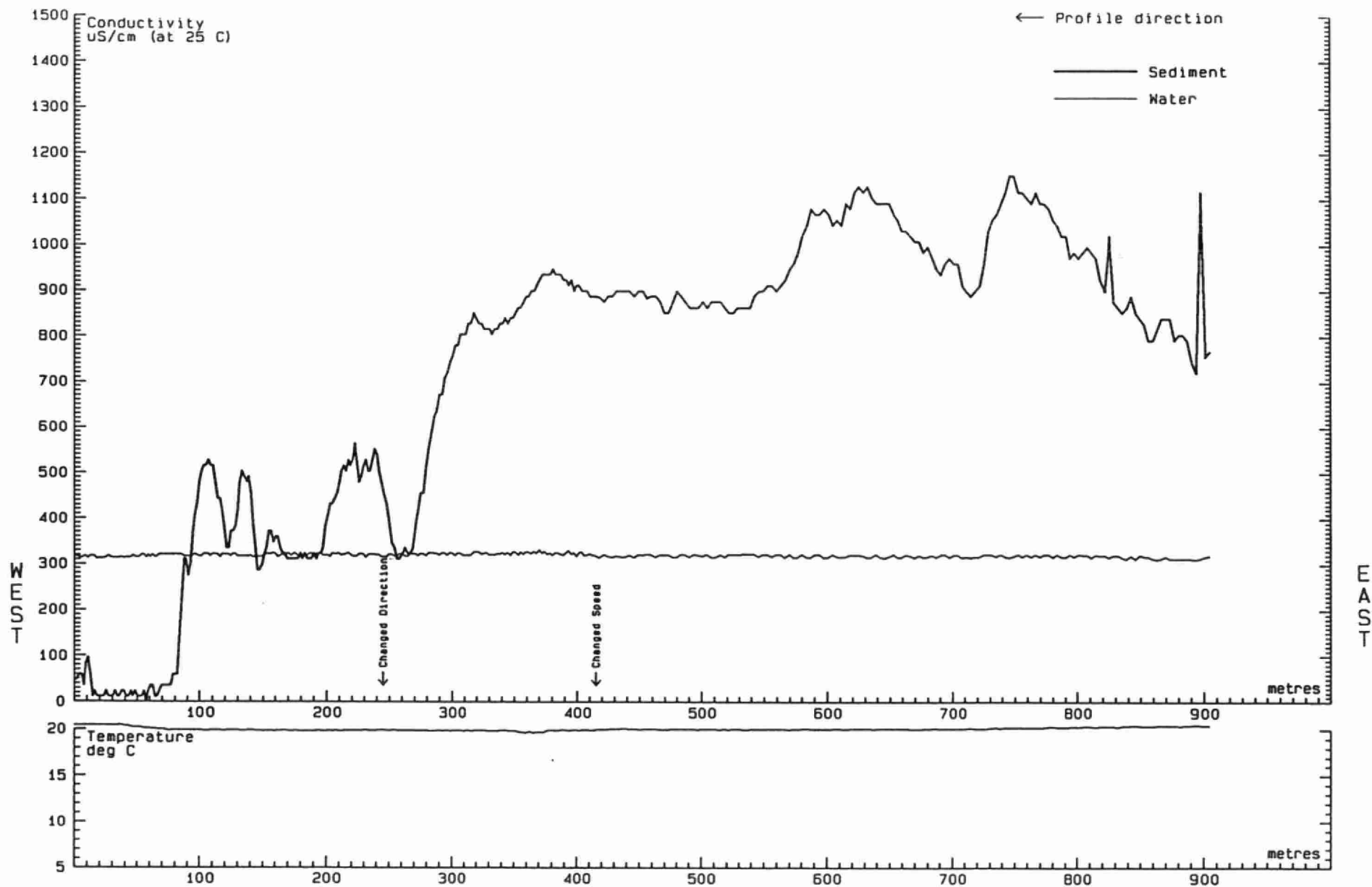Instrument in Horizontal Dipoles Mode
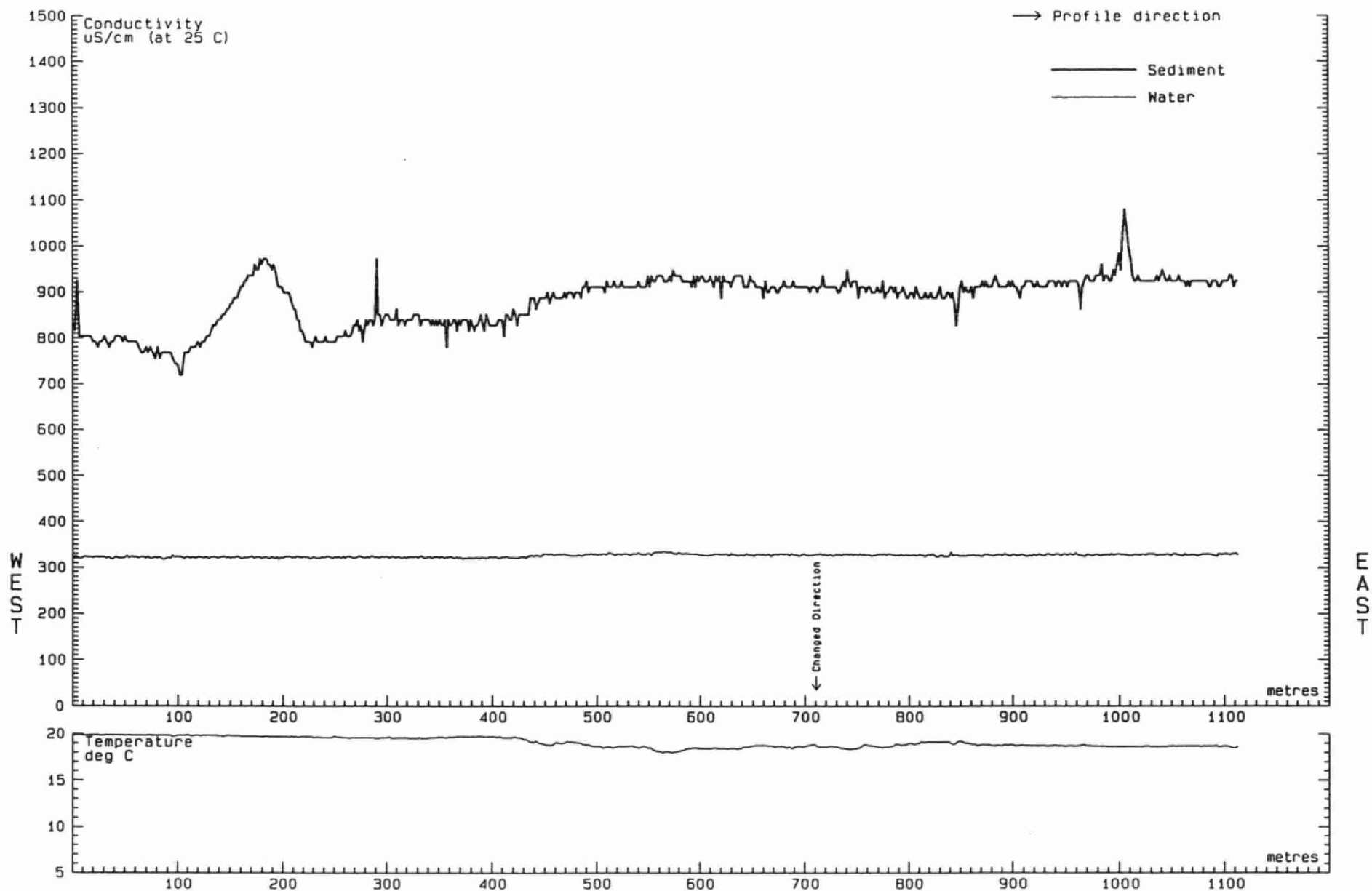
Fig. B-16   LINE 17   CATARAQUI BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

Fig. B-17   LINE 1B   CATARAQUI BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

APPENDIX C

Figure C-1

Figure C-2

Figure C-3

Map legend and labels:

500 E · 1000 E · 1500 E · 2000 E · 2500 E · 3000 E · 3500 E

3000 N
2500 N
2000 N
1500 N
1000 N
500 N

Millhaven Fibres Ltd

Liquifuels

Outlet

Outfall

H-wy 33

Parrots

Bay

Nicholsons Point

NORTH CHANNEL

Scale 1:20000

250   0   250   500   750
(metres)

ONTARIO MINISTRY
OF THE ENVIRONMENT

PARROTTS BAY
Lake Ontario, Kingston

BOTTOM WATER
TEMPERATURE

Survey carried out
September 12 & 13, 1989

Temperature in C degrees

GEOMAR GEOPHYSICS LTD.

Figure C-4

APPENDIX D

Fig. D-1   LINE 1   PARROTTS BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

Fig. D-1a   LINE 1   PARROTTS BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

Fig. D-2   LINE 2   PARROTTS BAY   SEPTEMBER 1989
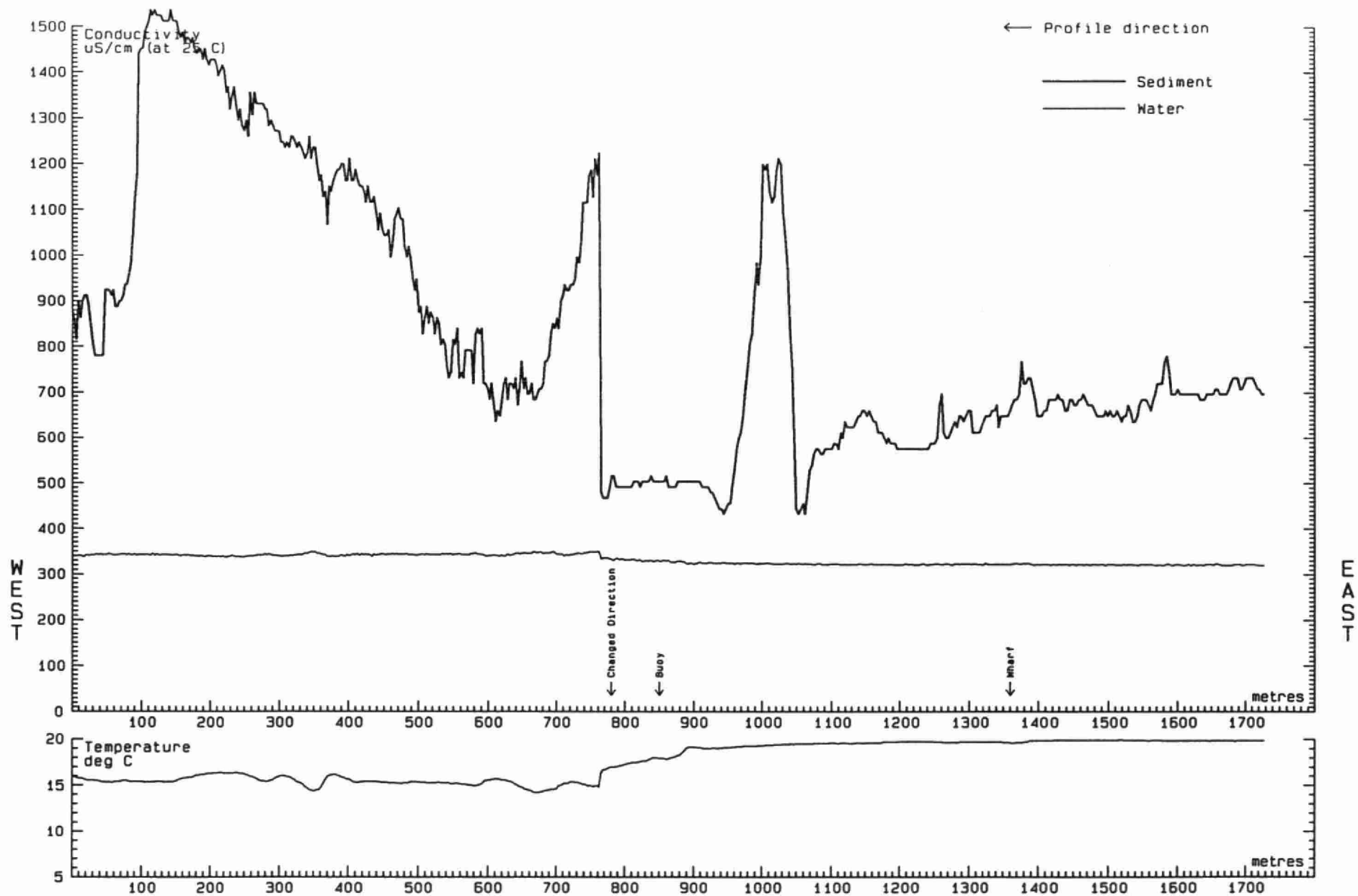Instrument in Horizontal Dipoles Mode

Fig. D-3   LINE 3   PARROTTS BAY   SEPTEMBER 1989
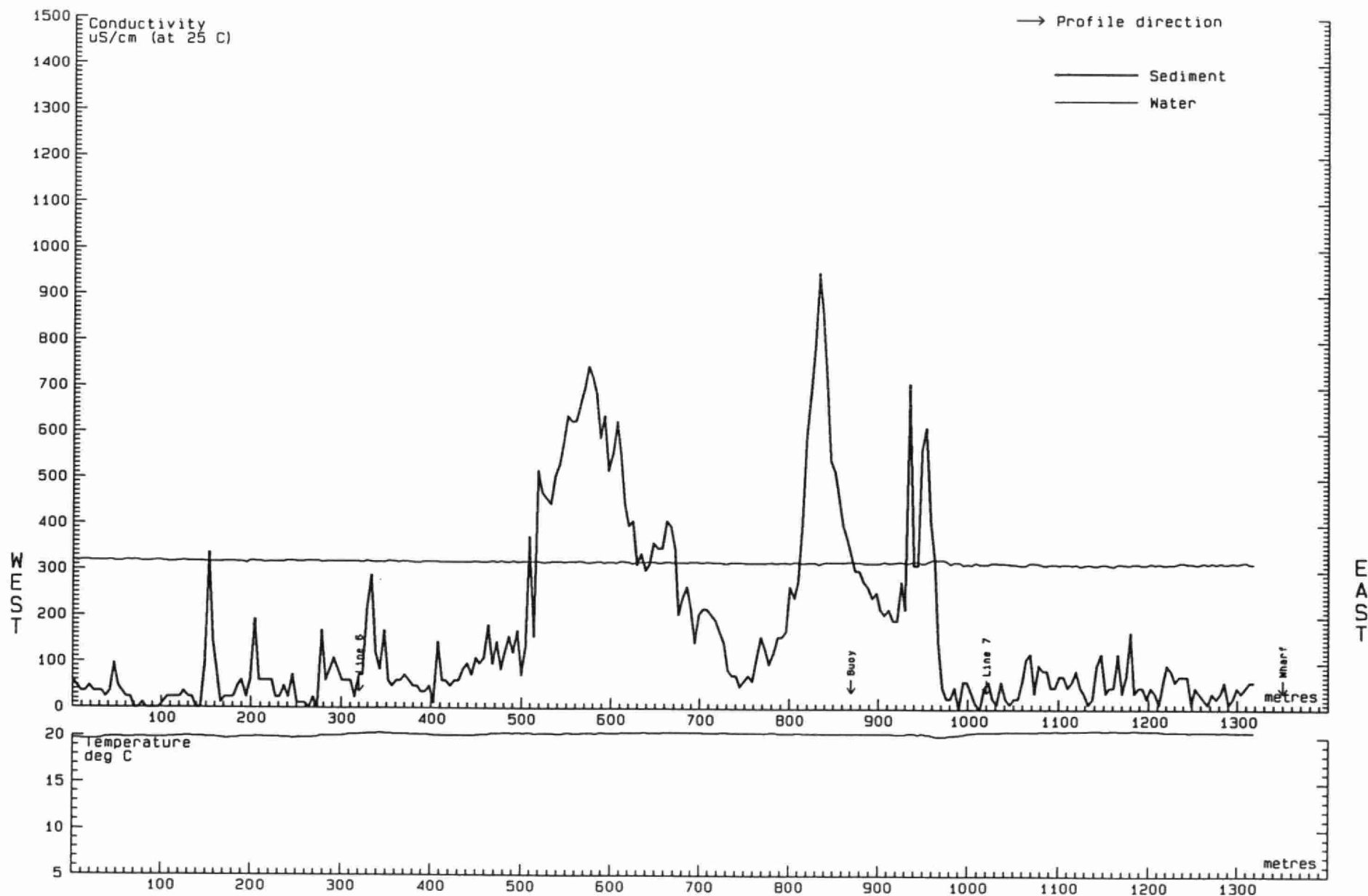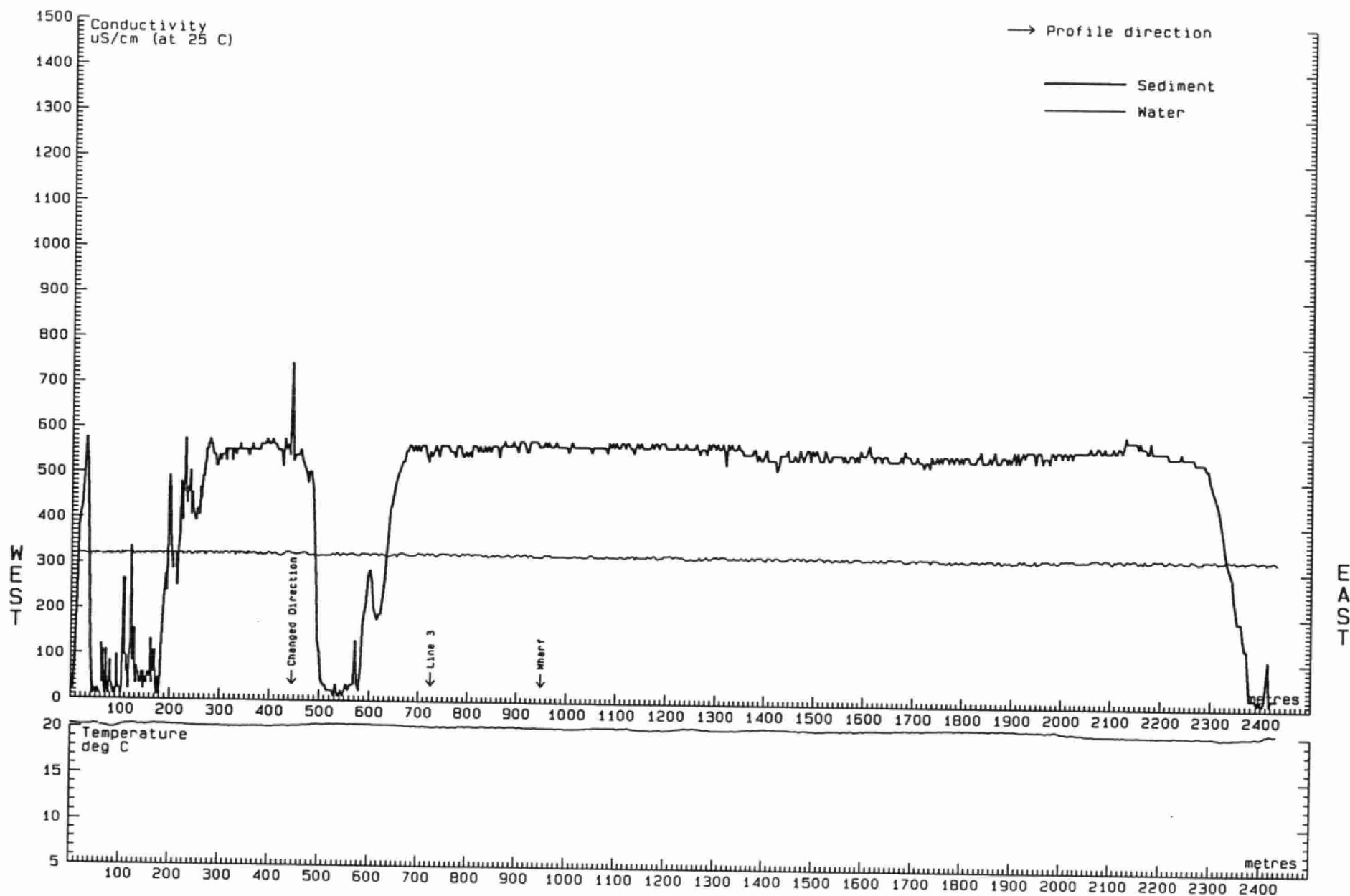Instrument in Horizontal Dipoles Mode

Fig. D-4   LINE 5   PARROTTS BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode

Fig. D-5   LINE 8   PARROTTS BAY   SEPTEMBER 1989
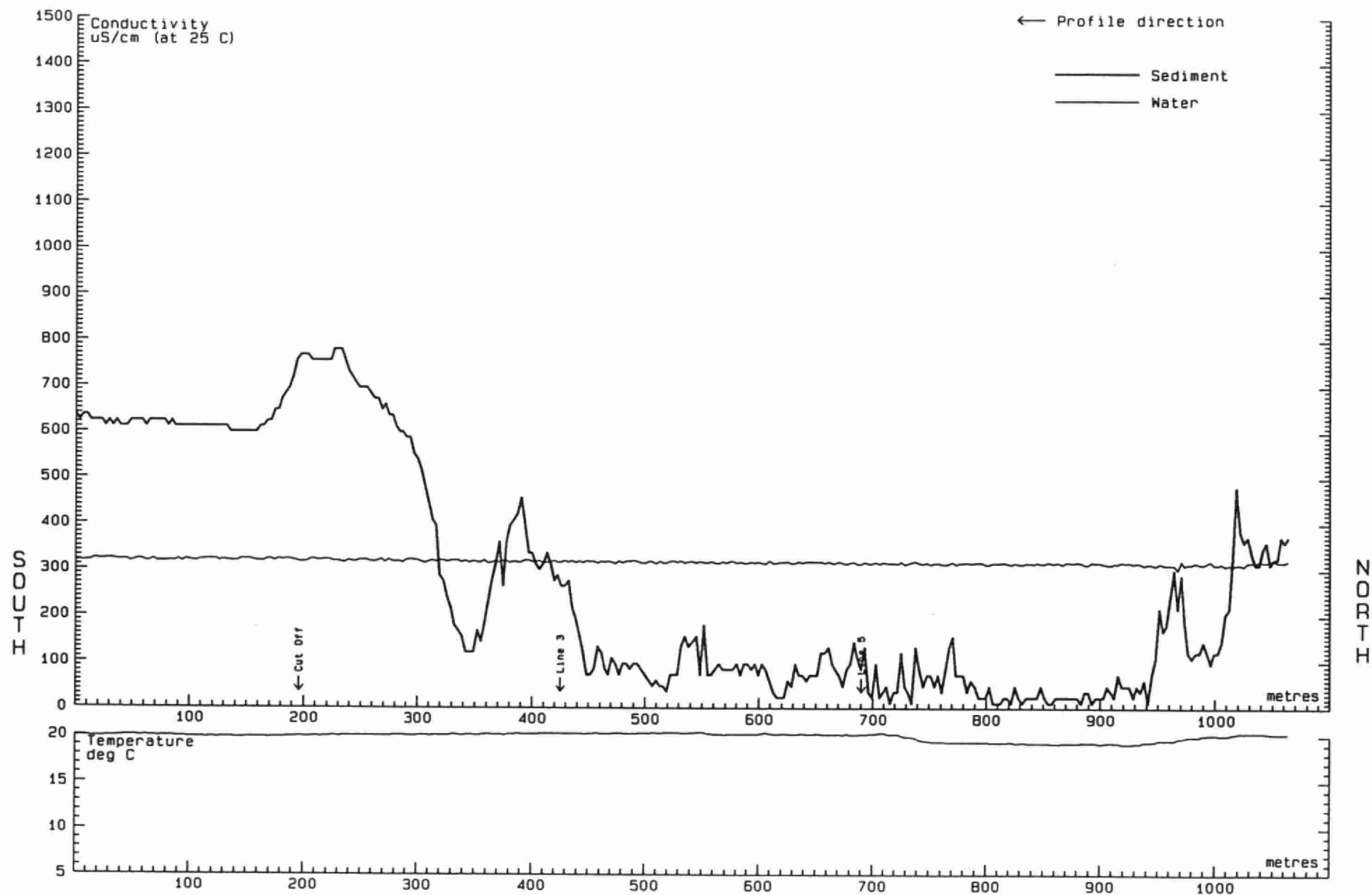Instrument in Horizontal Dipoles Mode

Fig. D-6   LINE 6   PARROTTS BAY   SEPTEMBER 1989
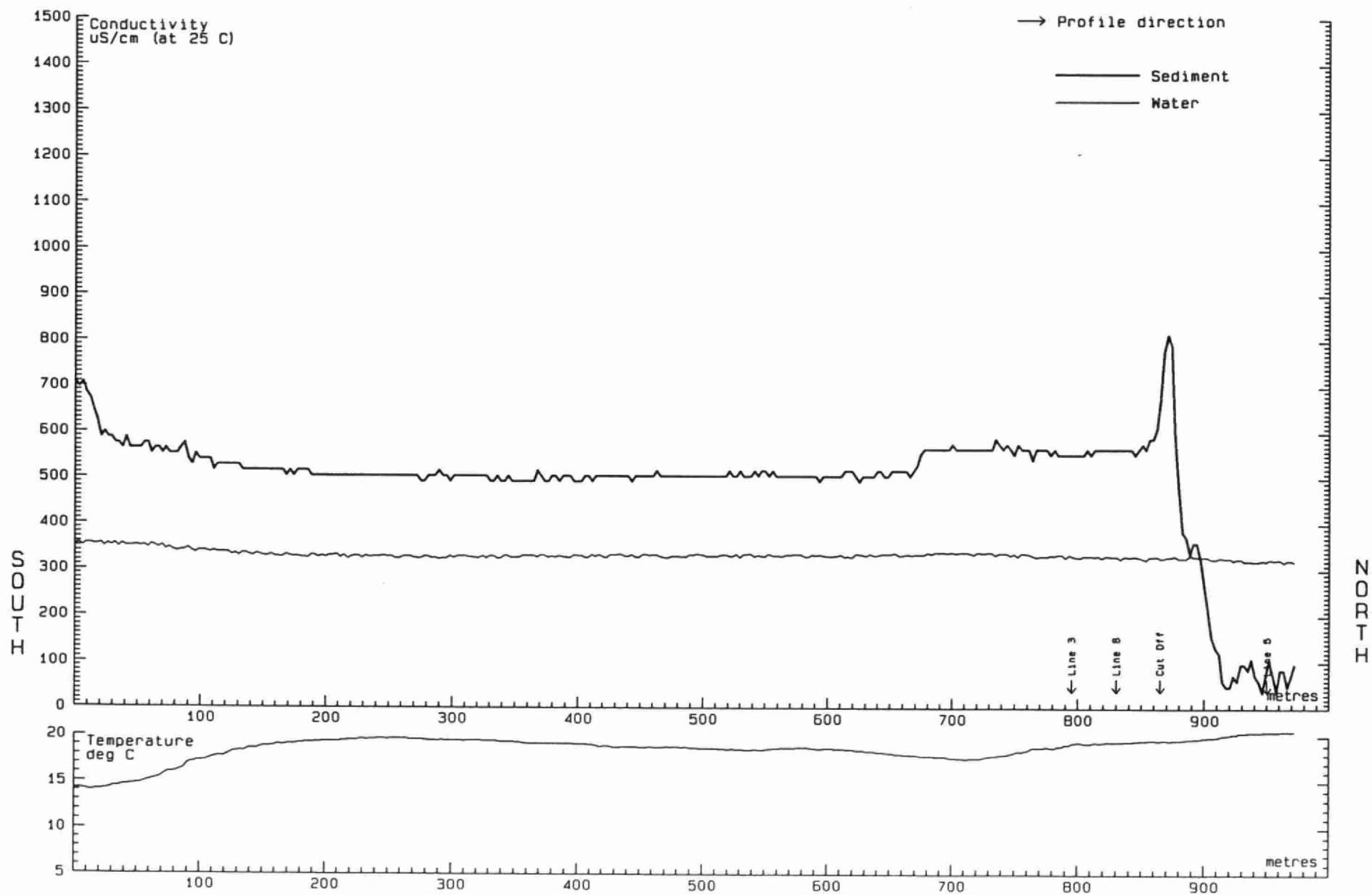Instrument in Horizontal Dipoles Mode

Fig. D-7   LINE 7   PARROTTS BAY   SEPTEMBER 1989
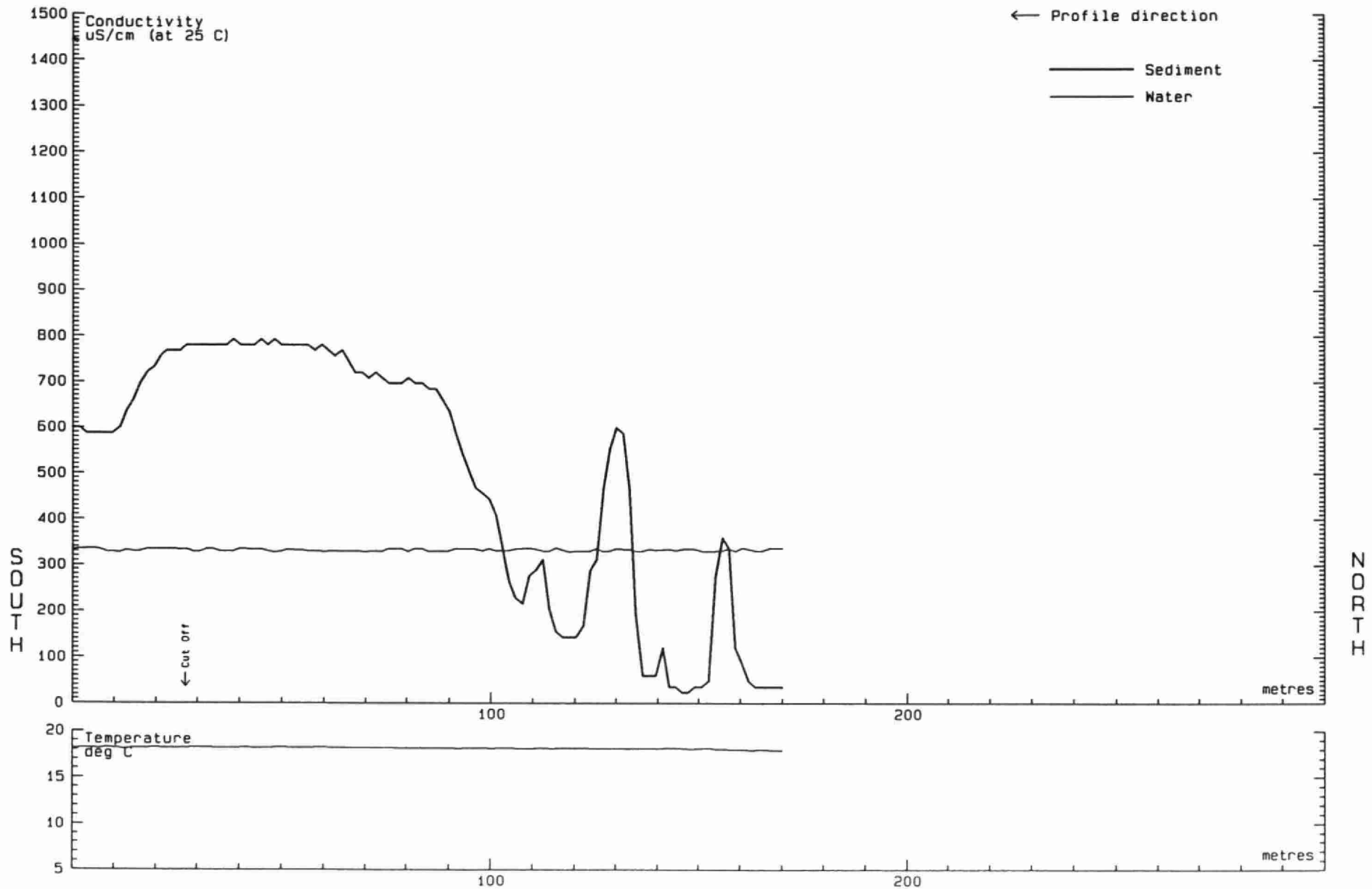Instrument in Horizontal Dipoles Mode

Fig. D-8   LINE 15   PARROTTS BAY   SEPTEMBER 1989
Instrument in Horizontal Dipoles Mode